SACRAMENTO RIVER SYSTEM
SALMON AND STEELHEAD PROBLEMS
AND ENHANCEMENT OPPORTUNITIES

A report to the

CALIFORNIA ADVISORY COMMITTEE

ON SALMON AND STEELHEAD TROUT

by

Richard J. Hallock

June 22, 1987

SACRAMENTO RIVER SYSTEM
SALMON AND STEELHEAD PROBLEMS
AND ENHANCEMENT OPPORTUNITIES

A report to the

CALIFORNIA ADVISORY COMMITTEE

ON SALMON AND STEELHEAD TROUT

#125 - J

by
Richard J. Hallock

June 22, 1987

SACRAMENTO RIVER SYSTEM SALMON AND STEELHEAD

PROBLEMS AND ENHANCEMENT OPPORTUNITIES

CONTENTS

FIGURES

Figure | Page

TABLES

SACRAMENTO RIVER SYSTEM SALMON AND

STEELHEAD - PROBLEMS AND OPPORTUNITIES

ABSTRACT

Total numbers of salmon that spawn in the Sacramento River system have declined more than 50% (75% in the upper river) since the 1950's. Fall-run salmon, which make up more than 90% of the total, appear to be stabilized at a low level of 200,000 fish; 85% spawn naturally and 15% are spawned artificially at hatcheries. However, on streams where there are hatcheries the populations are increasing, which is masking the true picture, i.e., the natural spawning populations are declining in the Upper Sacramento River system (above the Feather River).

Most of the known problems in the Sacramento River system, now limiting salmon and steelhead production, occur in the Upper Sacramento River and are apparently adversely affecting the natural stocks much more than the hatchery stocks. The two most important known recent causes of the salmon declines in the Upper Sacramento are Red Bluff Diversion Dam (RBDD) which has decreased salmon populations by 114,000 fish, and the Glenn-Colusa Irrigation District (GCID) diversion, which has decreased the salmon populations by 35,000 fish. Between the two, they could be depriving the fisheries of 300,000 salmon, at a two-to-one catch to escapement ratio.

A combination of mining pollution, flow fluctuations and warm water releases from the Shasta-Keswick Dam complex, lack of suitable spawning gravel and gravel recruitment, unscreened diversions (as well as inefficiently screened diversions), predation, and operation of the Anderson-Cottonwood Irrigation District (ACID) diversion dam and RBDD, cause an estimated 85% loss in natural stocks between eggs deposited in the gravel and smolts entering the ocean. The loss is not as great for hatchery production, partly because the size of fish released is greater and a large portion of the production is released at downstream sites, or in the bay.

Restoration of salmon populations in Clear, Battle and Butte Creeks could increase the salmon populations by 17,500 and steelhead by 1,300 fish. This salmon restoration could increase the fishery landings by 35,000 fish, at a two-to-one catch to escapement ratio.

There are 17 smaller Sacramento River system tributaries that now support a combined population of 9,000 salmon and 2,500 steelhead, and are contributing 18,000 salmon to the fisheries. The problems are many, but one way to help assure continued or increased production on these streams would be to assign a stream manager (like Larry Preston) to "oversee" the populations from the time the adults entered the streams until the juveniles had migrated out.

Carrying out the proposed plans to expand artificial production at four Sacramento River system facilities could increase total hatchery production by 70%, from the present 44 million to 74 million smolts, sub-yearlings and yearlings. There would also be an increase of at least 300,000 in yearling steelhead production. Based on the current spawning population size of 200,000 fall-run salmon, the natural spawners would still be producing about 70% of the juvenile outmigrants and the hatcheries 30%, but the size of hatchery fish would be much larger. Before going beyond this point

with increasing hatchery production, it would be appropriate to examine the effects of this increased hatchery production on the natural stocks.

The greatest potential future dangers to salmon and steelhead production in the Sacramento River system include the anticipated year 2020 water conditions, proposed power projects at ACID and RBDD, and continued bank stabilization with rock riprap.

ACKNOWLEDGEMENTS

Several colleagues made significant contributions to this report. The author expresses his deep gratitude to Frank Fisher, John Hayes, Dick Painter, Larry Preston, and George Warner (Ret.), of the California Department of Fish and Game, and Dave Vogel, of the United States Fish and Wildlife Service.

Special thanks are due Alan Lufkin, sport fishing representative on the California Advisory Committee on Salmon and Steelhead Trout, who made a memorable contribution to the report through invaluable assistance with the final preparation of the manuscript for publication.

Richard J. Hallock

INTRODUCTION

Sacramento River system salmon and steelhead populations, particularly in the upper Sacramento, have declined drastically since the 1950's, but now appear to be stabilized at less than half their former numbers. Many factors are now contributing towards holding these populations at the present low levels.

The purpose of this report is to provide the California Advisory Committee on Salmon and Steelhead Trout with a comprehensive assessment of the most important management issues and opportunities for maintaining and/or enhancing salmon and steelhead populations in the Sacramento River system.

The report examines the most important known factors now adversely affecting Sacramento River system salmon and steelhead populations. In addition, enhancement opportunities are pointed out, and recommendations made, which if implemented would increase the numbers of hatchery produced as well as naturally produced salmon and steelhead. Estimated fishery increases are based on the assumption that there will be no increase in habitat degradation or harvest rate.

Publications listed in the reference section constitute addenda that are essential for fullest understanding of this necessarily condensed report.

SALMON POPULATIONS

Description

All five species of the Pacific Salmon, genus Oncorhynchus, have been recorded in the Sacramento River system; however, salmon other than chinook, O. tshawytscha, are rare and they do not occur at all in the San Joaquin or Mokelumne River systems (Figure 1).

In the upper Sacramento River system (above the mouth of the Feather River) there are four runs or races of salmon named after the time they enter freshwater to spawn: spring, fall, late fall, and winter. Each run is a genetically distinct race that migrates into the river and reproduces within a specific time period. Thus during all months of the year adult salmon migrate into the upper Sacramento and spawn; and there are eggs incubating in the gravel, juveniles hatching and rearing, and juveniles migrating downstream during all months (Figure 2).

In the lower Sacramento River system, which includes the Feather, Yuba and American Rivers, the salmon populations are primarily fall-run, but some spring-run salmon spawn in the Feather River.

The U.S. Fish and Wildlife Service (FWS) has expressed concern that increased hatchery production of fall-run salmon might alter the genetic integrity of the natural stocks. However, the California Department of Fish and Game's (DFG) position on the genetic integrity of fall-run salmon in the Sacramento River system is that the fall-run constitutes a homogenous stock; electrophoretic evaluations failed to detect genetic differences between natural and hatchery produced populations. Therefore, DFG believes that the possibility of altering genetic integrity is not a valid reason to limit hatchery production of fall-run salmon.

Condition

Since 1953, spawning escapement data have been complete enough to enable estimates of fall-run and spring-run salmon for the entire Sacramento River system. Since 1967, a breakdown of the salmon counts at Red Bluff Diversion Dam (RBDD) has also provided spawning escapement data for the late fall- and winter-run populations above Red Bluff. During the 30-year period 1956-85 fall-run spawning escapements show a peak of about 425,000 in 1959 and a low of 102,000 in 1957. During the past 10 years, however, (1976-85) the fall-run salmon totals in the Sacramento River system have stabilized somewhat at an average of almost 200,000 fish (Figure 3, Table 1). About half of the current average total (96,000) spawn in the upper Sacramento River system and half (104,000) spawn in the lower Sacramento River system (46,000 in the Feather River, 14,000 in the Yuba River and 44,000 in the American River).

The overall decline in numbers of fall-run salmon, which make up more than 90% of the total, is due to decreasing populations in the upper Sacramento River system, whereas the Feather, Yuba and American River populations (lower Sacramento River system) have remained stable or increased (Figures 4 and 5).

In the upper Sacramento River system the decline in fall-run salmon is now occurring primarily among the numbers of salmon that spawn naturally above Red Bluff, not hatchery fish. Coleman National Fish Hatchery (CNFH)

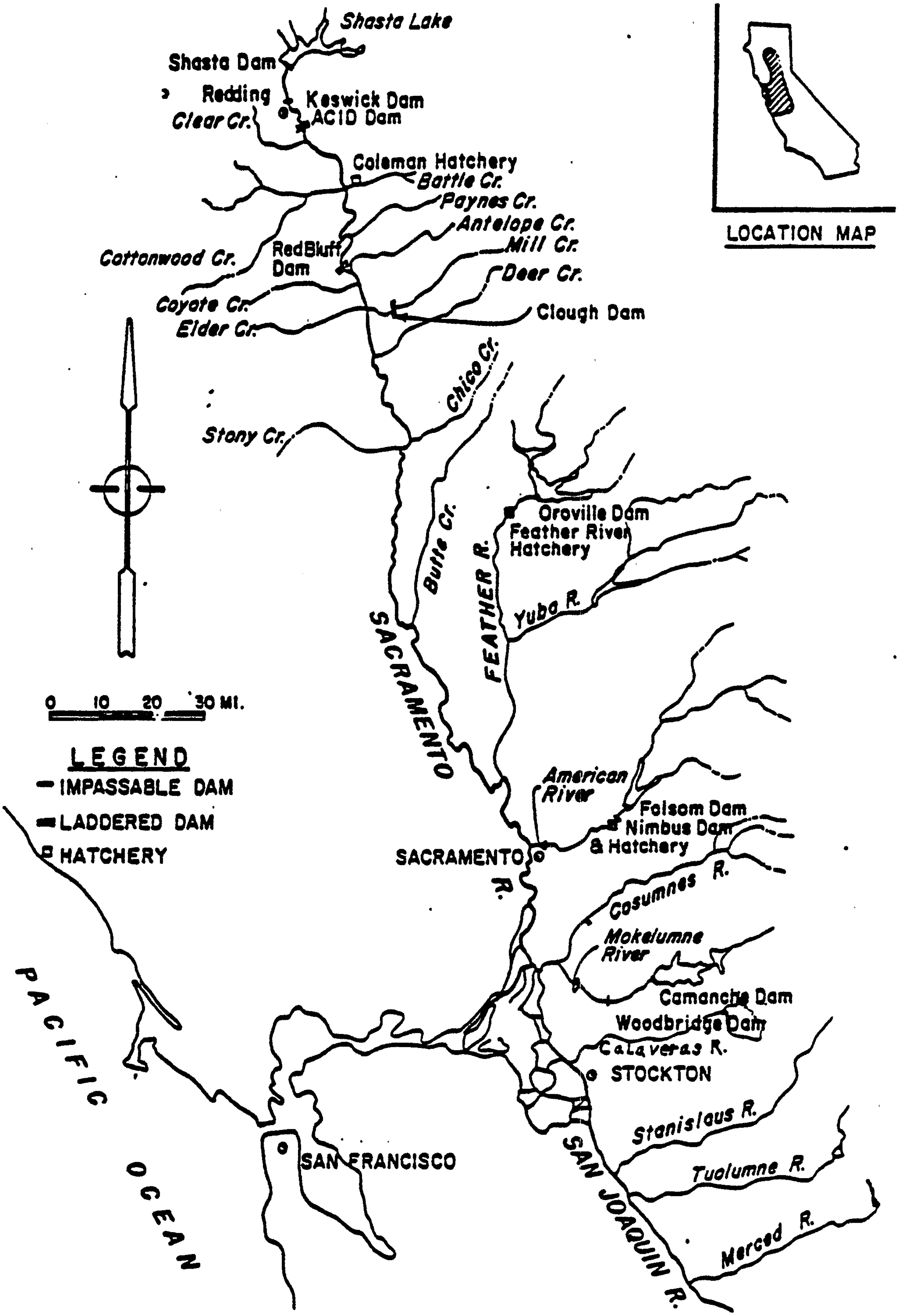

FIGURE 1. Salmon streams in the California Central Valley.

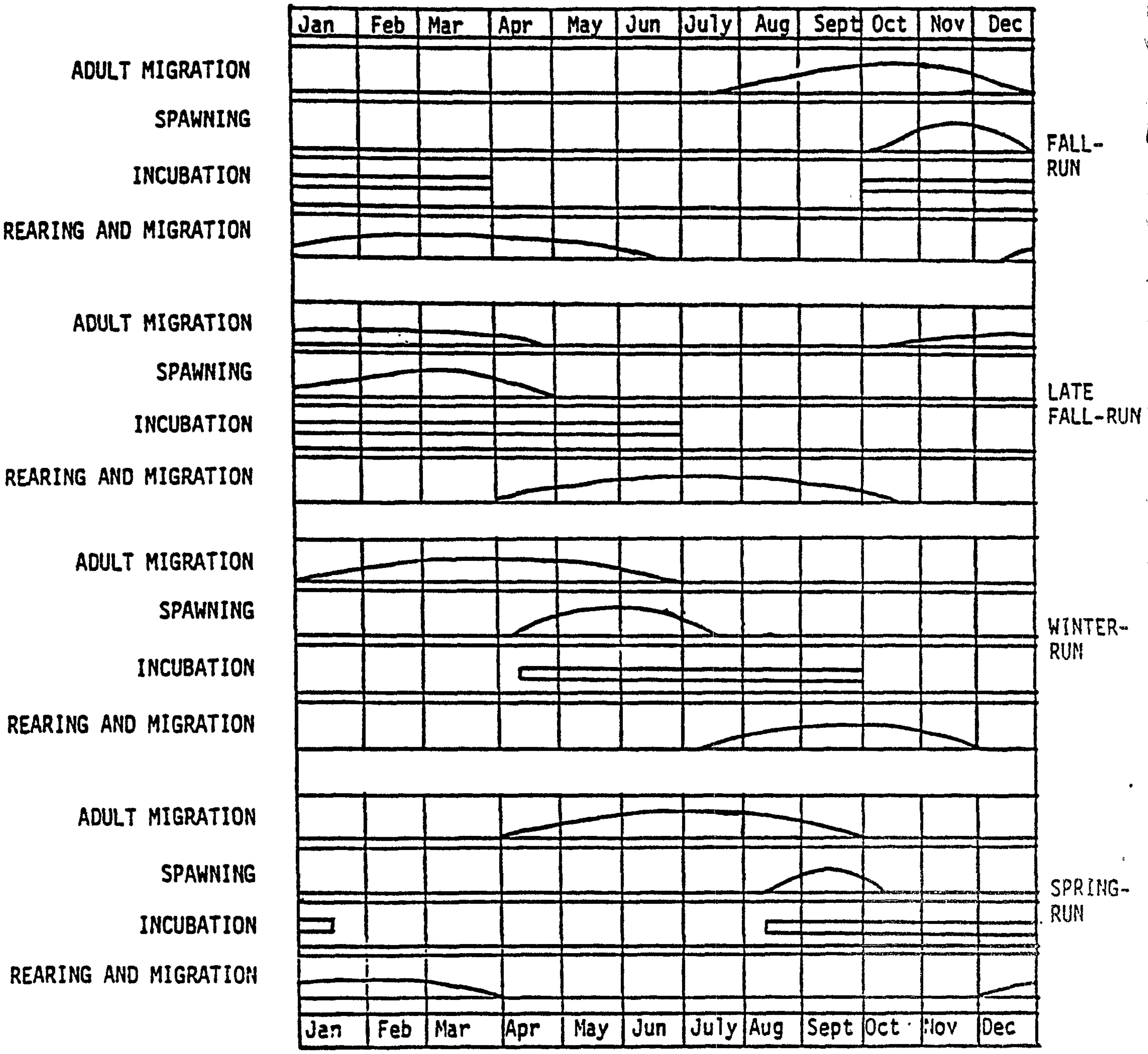

FIGURE 2. Life history stages of salmon in the Sacramento River. From U.S.F.W.S., 1983

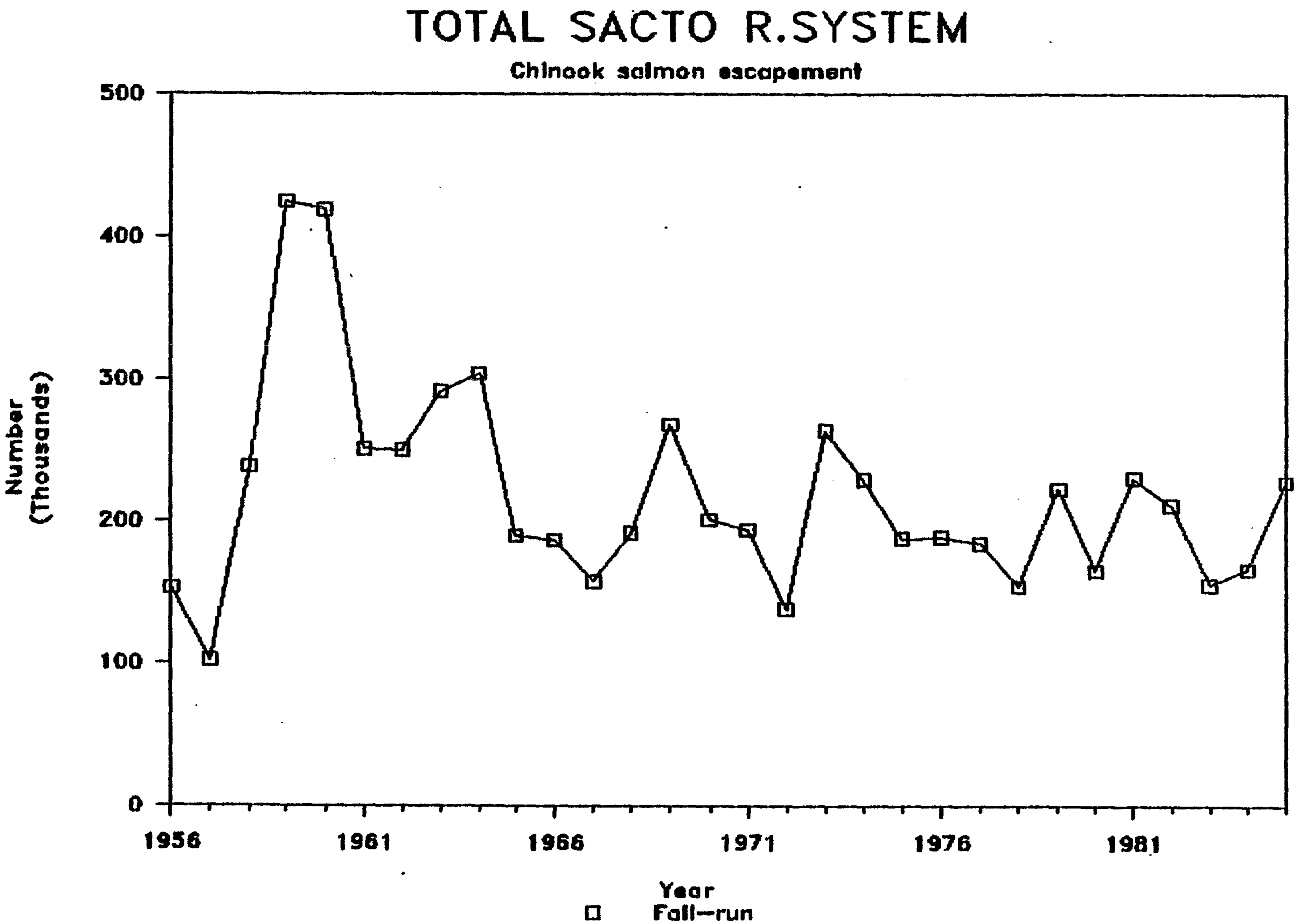

FIGURE 3. Fall-run salmon spawning escapement in the Sacramento River system.

	-----------------		TOTALS	----------	
	SACTO. R.	FEATHER	YUBA R.	AMERICAN	Grand Total
	0	0	0	0	0
1952	0	0	0	25000	25000
1953	0	0	0	28000	28000
1954	0	0	0	29000	29000
1955	0	0	0	17000	17000
1956	123463	18200	5000	6437	153100
1957	82536	10750	1205	7707	102198
1958	168966	34650	7900	26871	238387
1959	303451	80150	10000	31143	424744
1960	260695	83300	20400	54366	418761
1961	172626	43700	9200	25509	251035
1962	169478	19050	34300	27053	249881
1963	179530	33900	37000	41021	291451
1964	171559	38352	34900	59171	303982
1965	117765	23235	10200	38569	189769
1966	131181	20850	7800	26696	186527
1967	99040	11956	23500	23147	157643
1968	134995	18144	7000	31333	191472
1969	155105	60578	5230	47265	268178
1970	88384	61525	13830	37309	201048
1971	89281	47041	5650	51790	193762
1972	57721	46835	9258	24501	138315
1973	70912	73577	24119	94777	263385
1974	83648	65946	17809	61796	229199
1975	99379	43000	5641	39544	187564
1976	96390	60000	3779	28374	188543
1977	80443	46452	8722	48473	184090
1978	87535	37759	7416	21091	153801
1979	129948	32505	12430	47666	222549
1980	67538	35295	12406	49802	165041
1981	99076	53020	14025	64055	230176
1982	72191	55519	39367	43898	210975
1983	75567	30522	13756	35300	155145
1984	98014	50882	9965	38322	197183
1985	125706	56033	14066	65220	261025

Table 1. Fall-run salmon spawning escapement in the Sacremento River system.

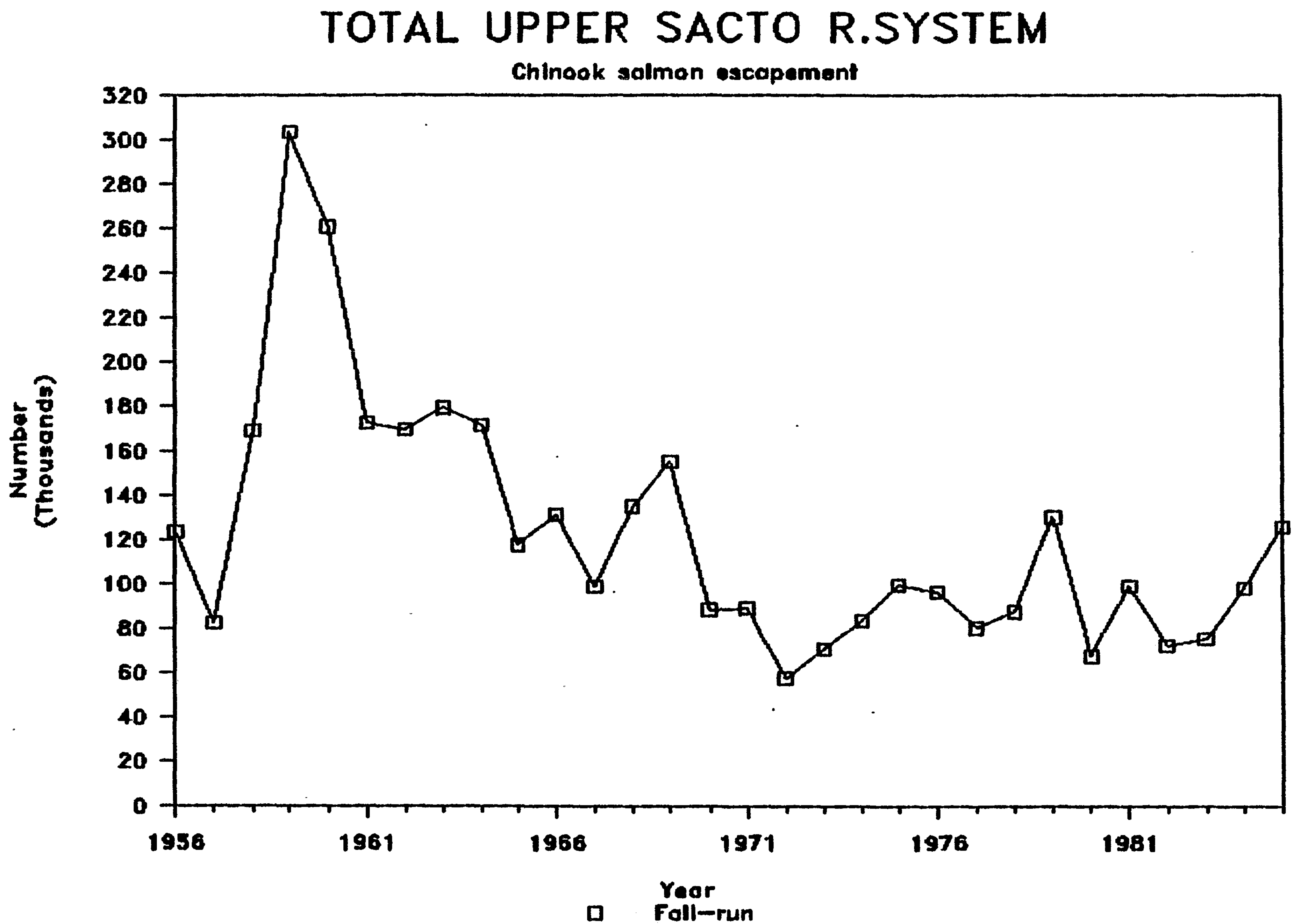

FIGURE 4. Fall-run salmon escapement in the Sacramento River system above the Feather River (upper Sacramento River system).

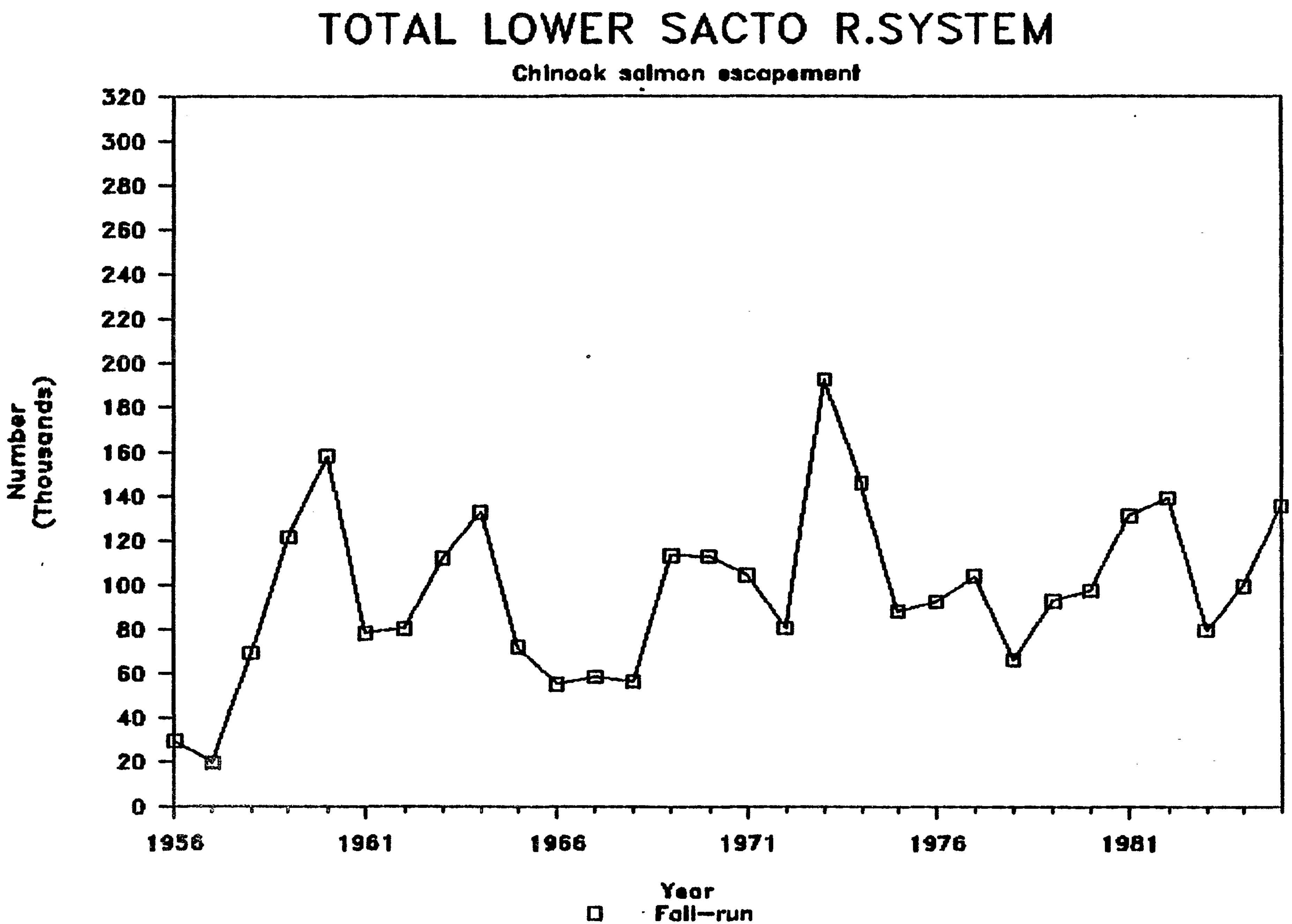

FIGURE 5. Fall-run salmon escapement in the Sacramento River system from the Feather River south (lower Sacramento River system).

production returns have increased since 1974 to where the combined numbers of salmon handled at the hatchery and spawning in Battle Creek now consist of 40% of the total fall-run salmon spawning above Red Bluff (Figure 6).

The counts at RBDD between 1967 and 1986 also indicate substantial declines in the late fall- and winter-run salmon populations, as well as the steelhead population, but not in the spring-run populations (Figures 7, 8, 9, 10).

As noted in greater detail elsewhere in this report (See p. 54 ff.) the American Fisheries Society has petitioned that the Sacramento winter-run chinook be declared a threatened species.

Population Model

Significant correlations have not been demonstrated between the size of Sacramento River salmon escapement one year and the escapement size three and/or four years later. However, the size of a spawning run has been correlated with the size of the immediately preceding season's ocean catch: a large catch is followed by a large escapement and a small catch by a small escapement. In addition, significant correlations have been demonstrated between spring outflow and adult fall-run salmon escapement 2½ years later: a large spring outflow results in a large escapement. These relationships point out that there are limiting factors affecting escapement between spawning time and the time a population is recruited to the fishery. Based on these facts and upon studies which have been conducted with Sacramento River salmon, a simple model can be constructed to approximate a stabilized life cycle of Sacramento River fall-run salmon (Figure 11). The model points out where the greatest losses occur and the areas where the greatest effort should be made to maintain or enhance the populations without having to reduce the catch.

The model indicates that there is an 85% loss between eggs deposited in the gravel and the resulting smolts entering the ocean, a 99% loss between smolts entering the ocean and resulting catchable fish entering the fishery. There is also a 65% loss of catchable fish due to the ocean sport and commercial fisheries and a 10% sport fishery loss of adults in freshwater; about a two-to-one catch to escapement ratio or harvest rate of 67% (Figure 12).

Although it does not follow that an increase in one area of the cycle will result in an equal increase in the following areas, due in some instances to density dependent mortality, fingerling salmon marking and trucking studies have shown, in an indirect manner, that increases in smolts reaching the ocean increase numbers caught and numbers returning to spawn. For example, if equal numbers of smolts are released in the upper Sacramento River and in the Delta, it is assumed that the greater catch and spawning escapement resulting from those released in the Delta is due to losses incurred by those that had to migrate 200 miles, even though actual numbers of each group entering the ocean were not measured.

Although the exact relationship between numbers of juveniles reaching the ocean and the following catch and escapement is not known, until that relationship and the optimum number is known, every effort should be made to put the greatest number of juveniles into the sea that hatcheries and the natural environment can produce. One thing is certain: if no juveniles reach the ocean there will be no catch or escapement.

There is also an optimum number of salmon spawners for present Sacramento River system environmental conditions, beyond which they will produce no

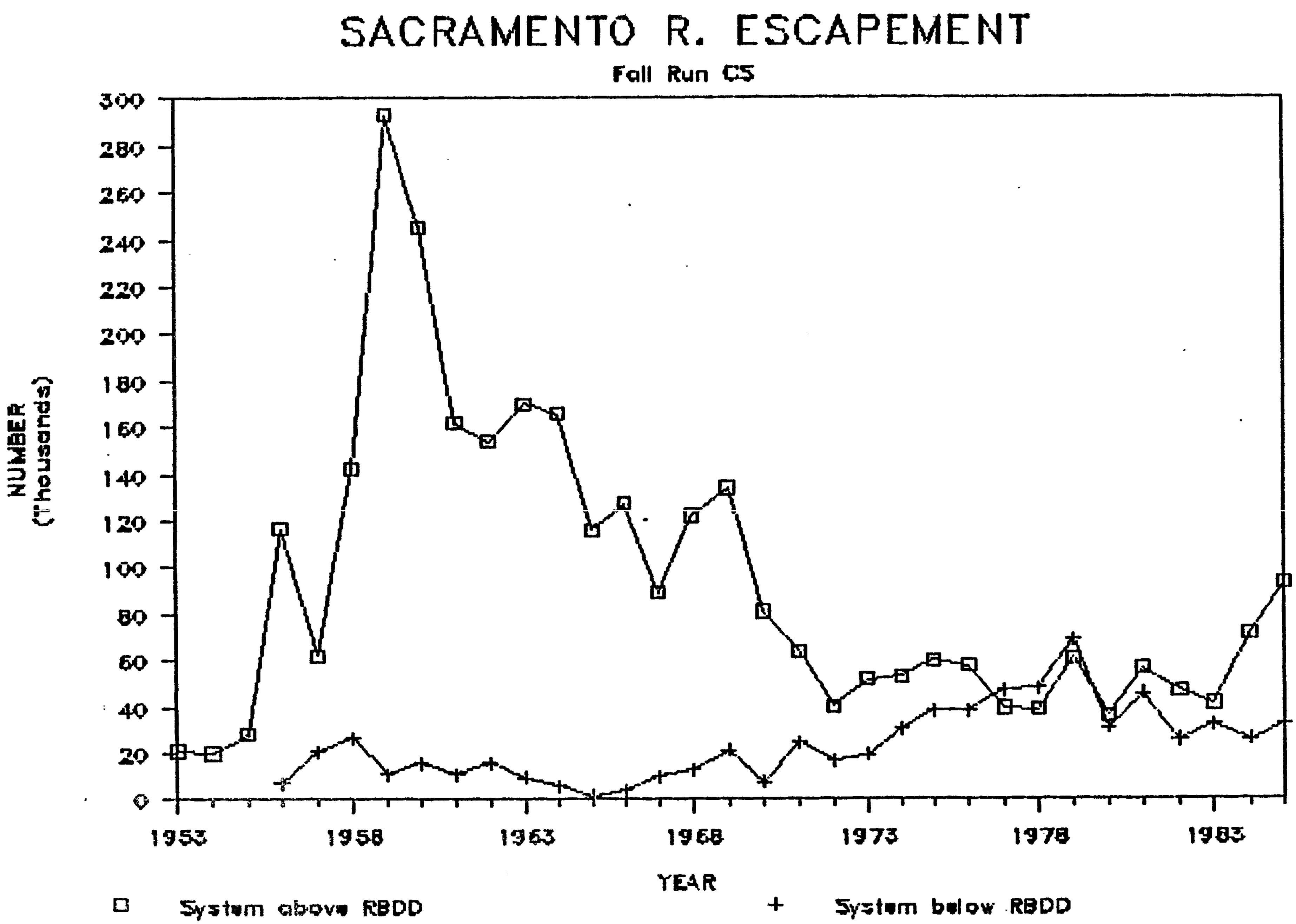

FIGURE 6. A comparison between the total fall-run salmon spawning populations in the Sacramento River system above Red Bluff (line with square symbols) and the total fall-run salmon spawning populations in Battle Creek (line with plus symbols).

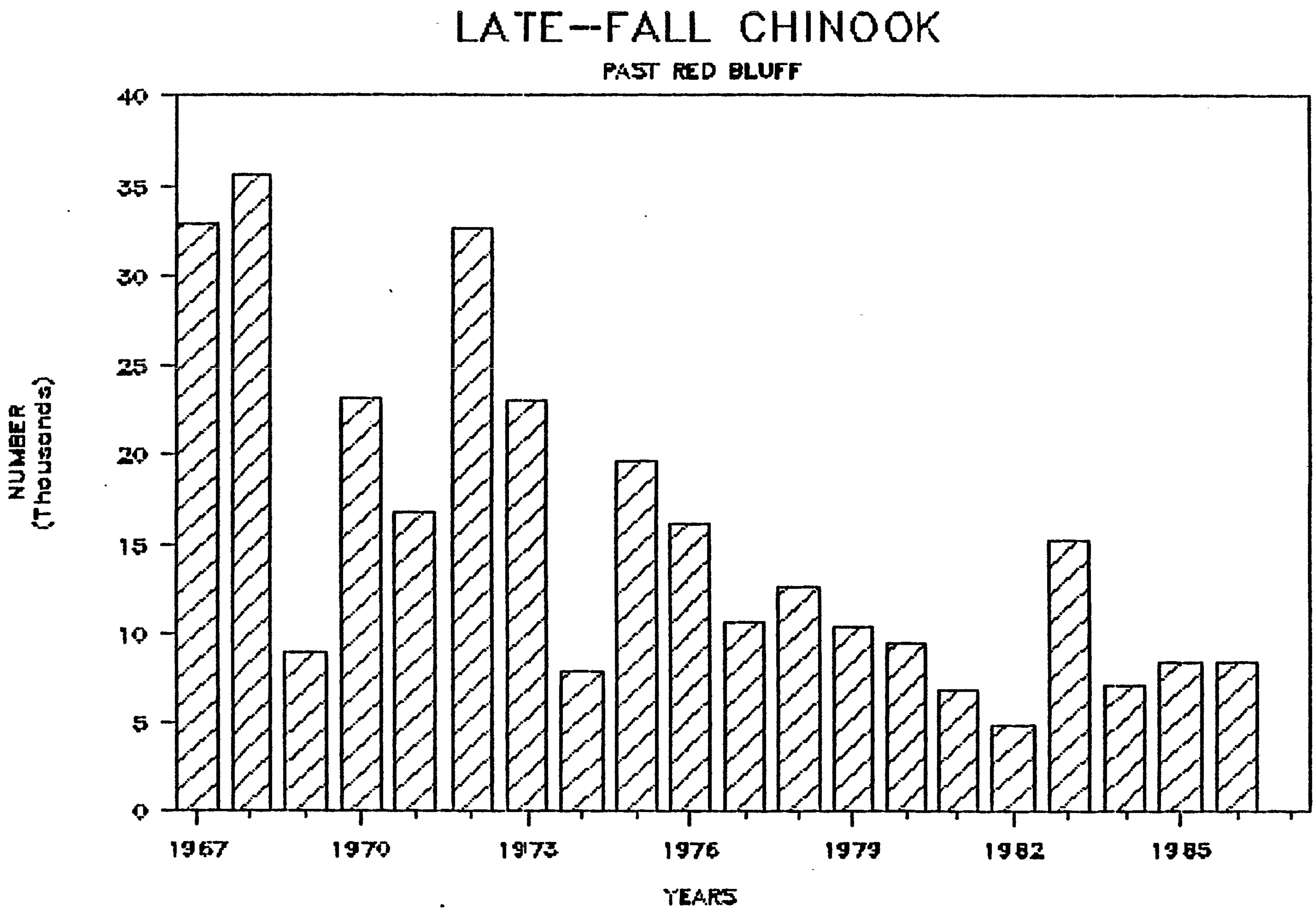

FIGURE 7. Numbers of late fall-run salmon counted at Red Bluff Diversion Dam.

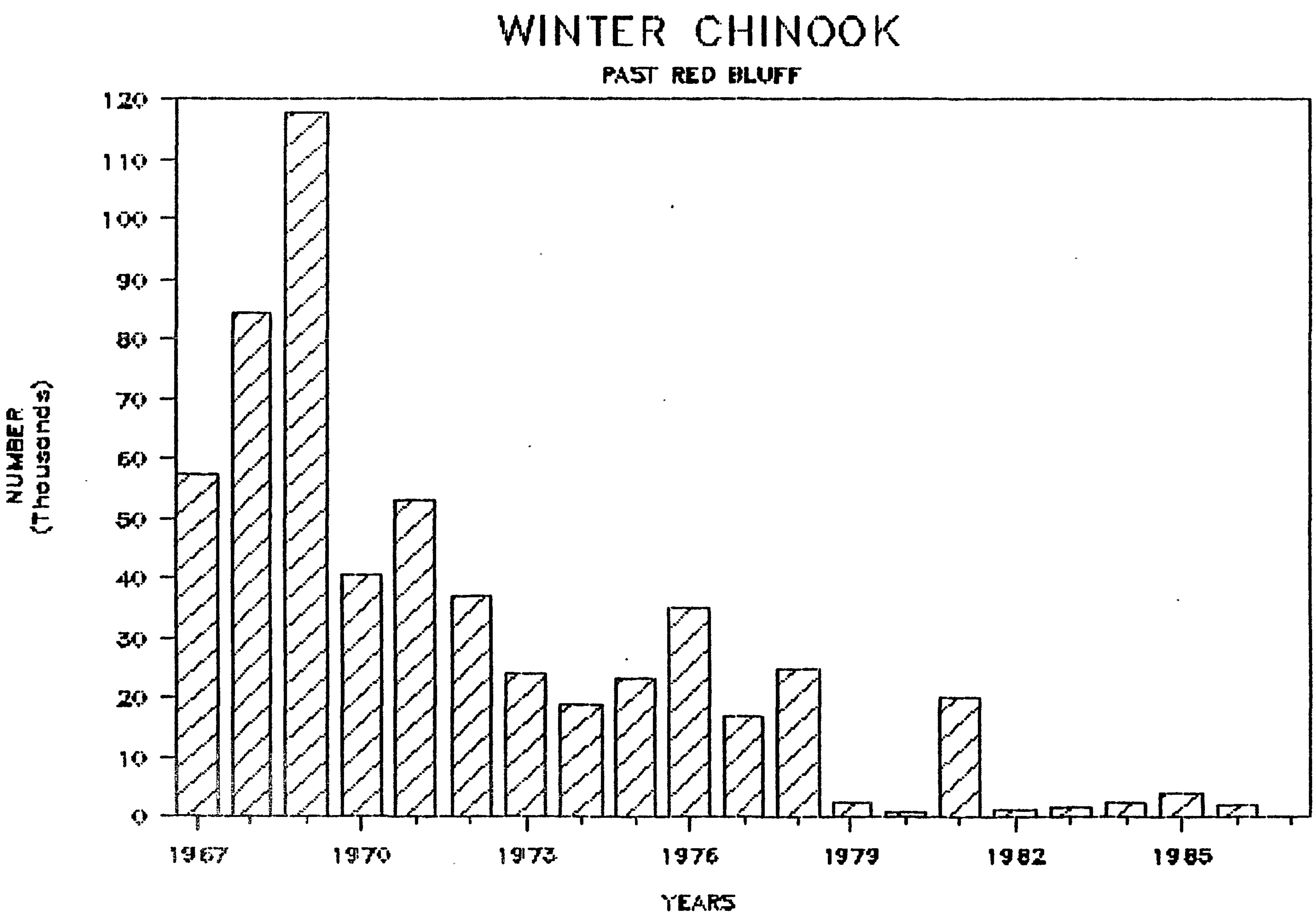

FIGURE 8. Numbers of winter-run salmon counted at Red Bluff Diversion Dam.

D-019867

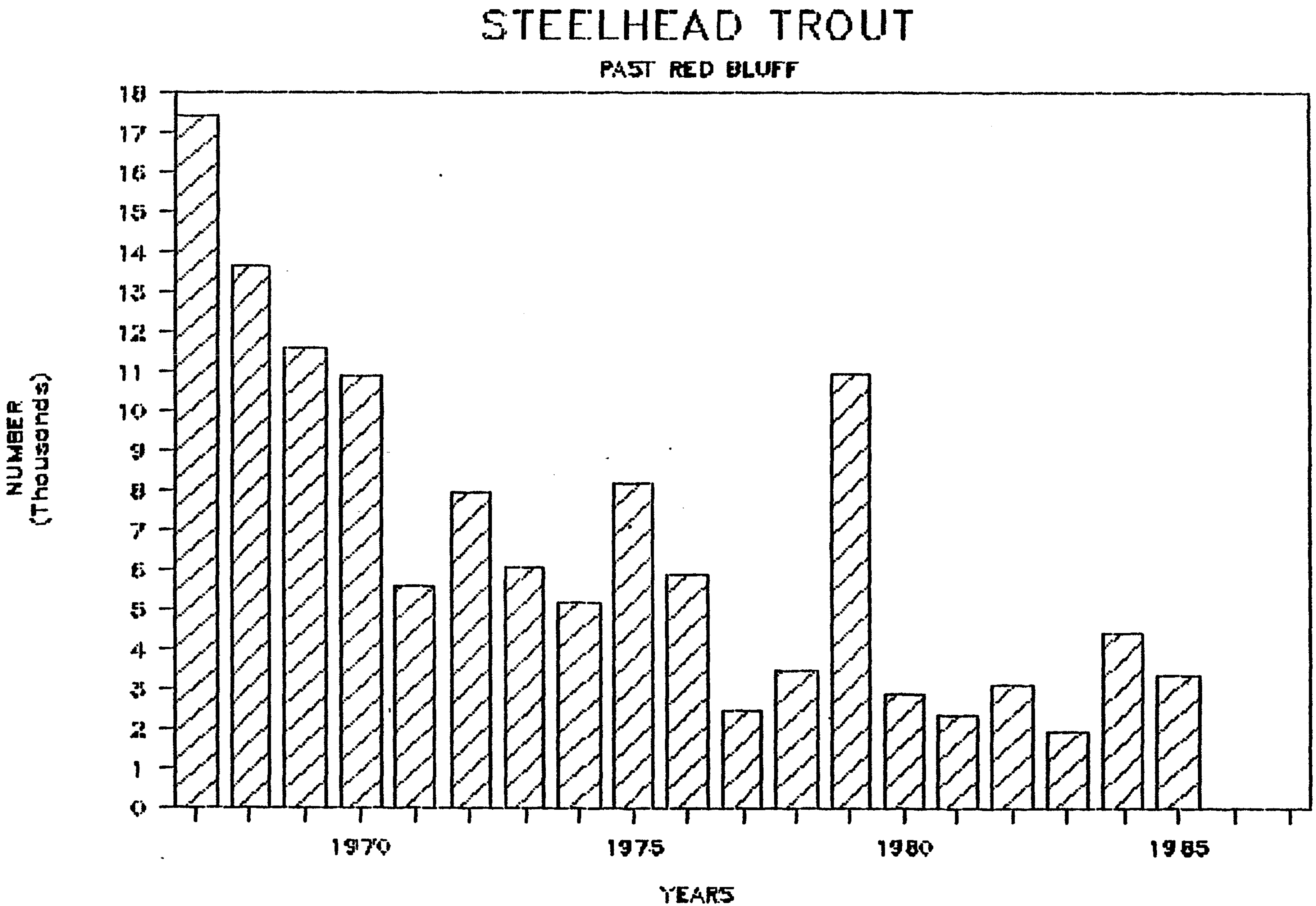

FIGURE 9. Number of steelhead trout counted at Red Bluff Diversion Dam.

D-019868

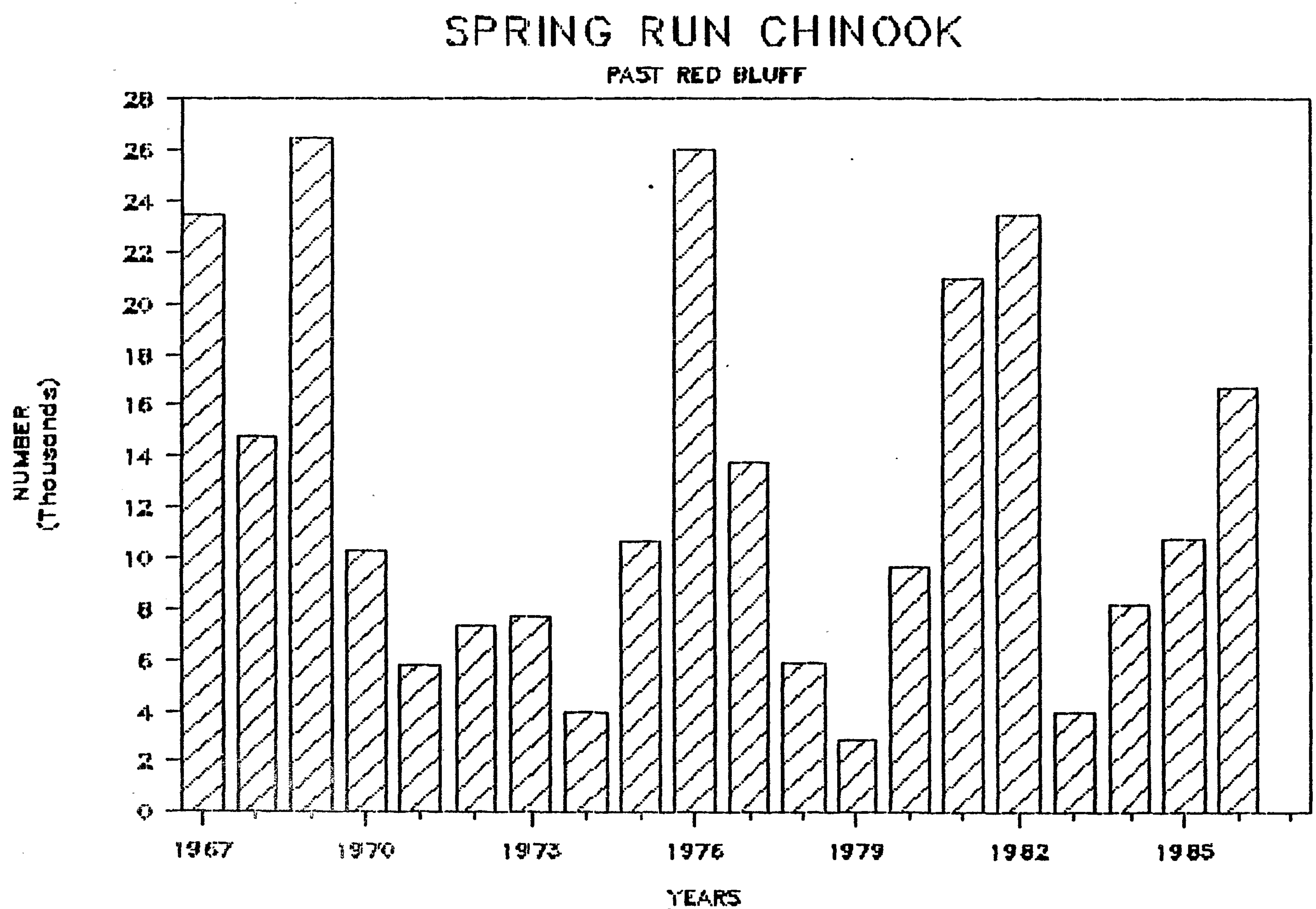

FIGURE 10. Numbers of spring-run salmon counted at Red Bluff Diversion Dam.

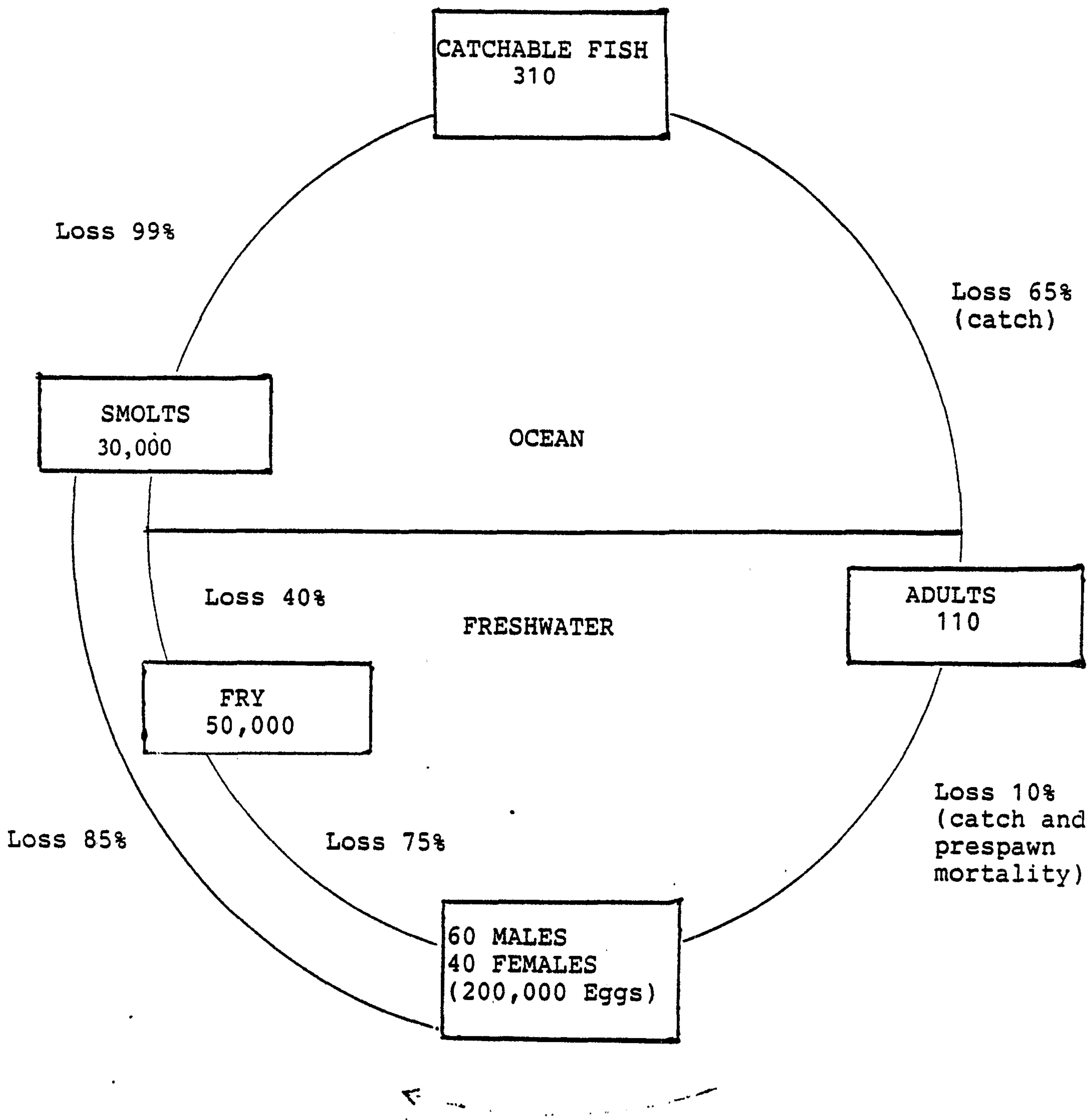

FIGURE 11. Probable life cycle of a Sacramento River system salmon population of 100 fish, stabilized under present conditions of environment and catch.

D-019870

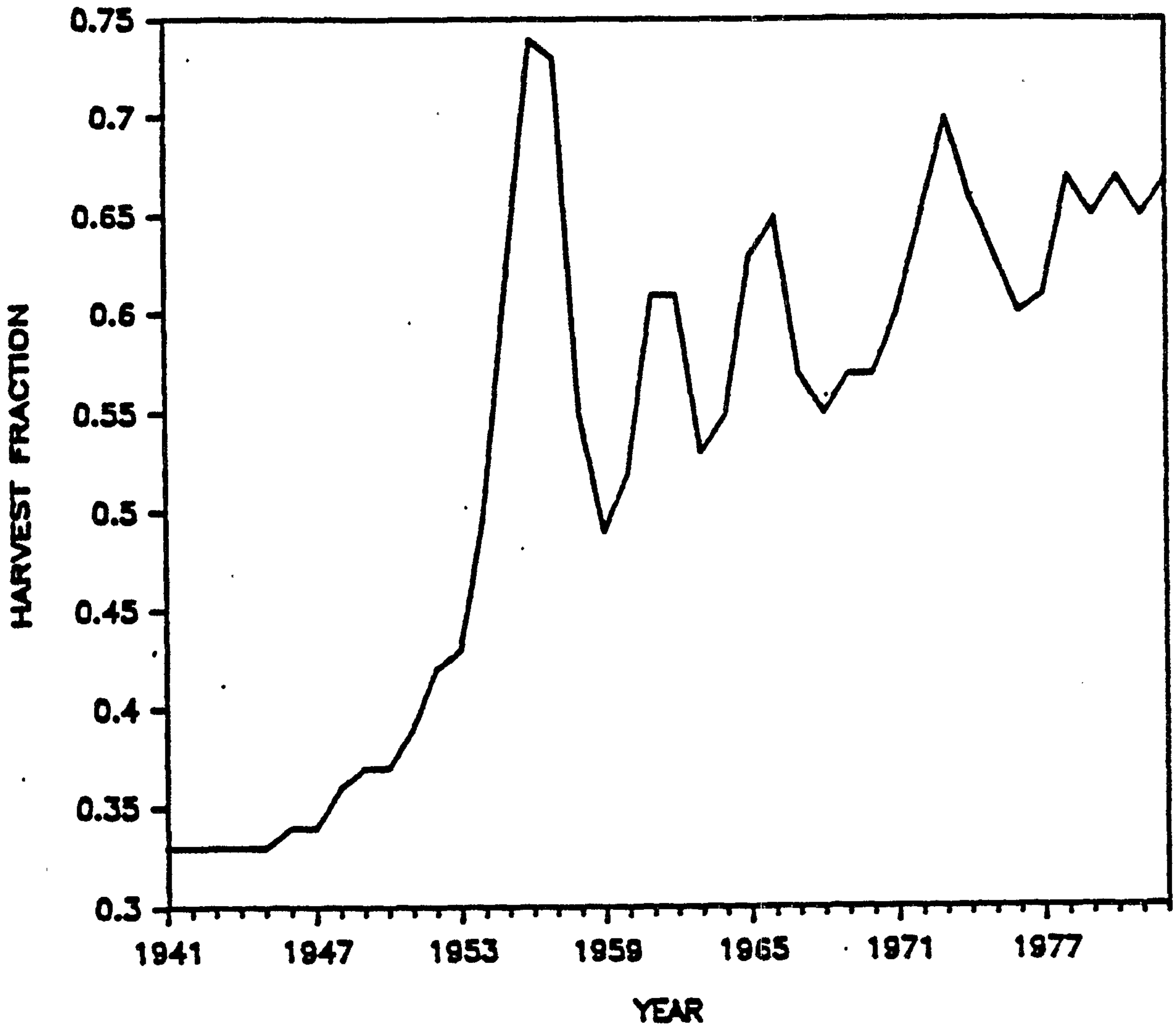

FIGURE 12. Estimated harvest fraction for California Chinook Salmon (harvest fraction = catch ÷ catch + escapement). From Reisenbichler, 1982.

D-019871

additional recruits, and should be harvested. That is why management goals for the numbers of spawning salmon must be set correctly; too many spawners is a waste, too few will start the cycle spiraling downward.

A model for winter-run salmon would be similar to the fall-run model but based upon a catch to escapement ratio of less than one-to-one (0.66 to 1), indicating that there would be fewer catchable fish produced, and a smaller catch. A late fall-run salmon model would be quite similar to the fall-run model, while a spring run model would be closer to the winter-run model, since the catch to escapement ratio is also lower than that of fall-run salmon.

STEELHEAD POPULATIONS

Description

Adult steelhead trout, Salmo gairdnerii gairdnerii, migrate into the upper Sacramento River system primarily between July and the middle of the following March, with a peak at the mouth of the Feather River near the end of September. In the American and Feather Rivers the length of the migration period is similar, but the peak does not occur until December or January. Spawning occurs in most tributaries to the Sacramento River, with year-round flows, from the latter part of December through the following March or April. Immediately after spawning, most steelhead start the journey back to sea. Only 14% survive to spawn a second time, and 2% a third time. 83% are first-time spawners.

More than 90% of the steelhead in the Sacramento River system are now produced by three hatcheries: Coleman, Feather River and Nimbus.

Condition

Since the mid 1960's steelhead populations in the upper Sacramento have declined, and are now less than half their numbers in the 1950's. They have decreased from more than 20,000 in the 1950's to less than 5,000 in the 1980's. In 1983 the count reached a nadir of 2,000 fish. Most of the decline has occurred since 1966, when RBDD began operating.

In the American and Feather Rivers there has been no decline in the steelhead populations, and the Yuba River continues to support a modest population of naturally produced steelhead. In the American and Feather Rivers the populations are holding at nearly 20,000 each, and an estimated 2,000 steelhead now spawn in the Yuba River, according to DFG.

Fishery Management Recommendation

Many of the problems related to the steelhead fishery involve hatchery production and stocking policies, which are addressed as appropriate in report sections where hatcheries are discussed. To help those populations in particular that spawn naturally, the fishery should be managed as an adult fishery only. Fishing for juvenile steelhead should be stopped in the upper Sacramento, at least until the adult populations return to suitable levels. In addition, catchable trout planting in most designated steelhead streams (DFG Steelhead Trout Policy, 8-15-75) should be discontinued and current exceptions to the policy voided.

UPPER SACRAMENTO RIVER SYSTEM MAJOR PROBLEMS

The greatest decline among naturally spawning fall-run salmon above Red Bluff has occurred among those that spawn in the Sacramento River in the Redding area (Figure 13). This is the upper part of the area, which extends at least down to Anderson, adversely affected by mining pollution, lack of spawning gravel, fluctuating flows and operation of the Anderson-Cottonwood Irrigation District diversion dam.

Mining Pollution

Iron Mountain Mine

One of the major factors contributing to the salmon population declines in the Sacramento River between Keswick Dam and Anderson is pollution from Iron Mountain Mine, located in the Spring Creek drainage (a tributary to the Sacramento River) near Redding. The pollution is in the form of lethal heavy metals present in acid mine waste. The waste contains, among other metals, zinc, copper and cadmium, all of which are toxic to salmon at concentrations much less than one part per million. The acid mine waste from Iron Mountain Mine is now generated by oxidation of pyrite ore in water, which produces sulfuric acid (pyrite, used in the manufacture of battery acid, has been mined since 1962 when copper mining was stopped.) The sulfuric acid, in turn, dissolves the zinc, copper and cadmium deposits, and the resulting waste flows and/or leaches into the Spring Creek drainage.

Historically, the acid mine waste from Spring Creek has polluted the Sacramento River since the 1880's when Iron Mountain Mine opened. However, prior to construction of the Shasta-Keswick Dam complex in the early 1940's natural high flows from the Sacramento River system upstream from Redding coincided with those from Spring Creek, and diluted the toxic wastes from Spring Creek to levels tolerable to fish in the Sacramento River downstream from Spring Creek. The fish kills were limited to the immediate area of the confluence of Spring Creek and the Sacramento River; they now occur as far downstream as Anderson.

Spring Creek Debris Dam

Spring Creek Debris Dam was constructed in 1963 to receive and store waste flows from Iron Mountain Mine so that they could be released at safe levels based upon developed schedules (pollution control by dilution manipulation). These schedules are considered to be interim only, as more information needs to be gathered. Construction of Spring Creek Debris Dam has helped to alleviate the fish mortality problem; however, fish kills have been reported on at least seven different occasions since the dam was constructed: 1964, '69, '78, '80, '81, '83 and '86. The extremely large fish kill in 1969, when the debris dam overflowed without corresponding dilution flows from Shasta Dam, especially points out that the present problem is far from being under control.

Although the problem of toxicity has been regularly documented in the Sacramento River, the magnitude of fish losses caused by toxicity has

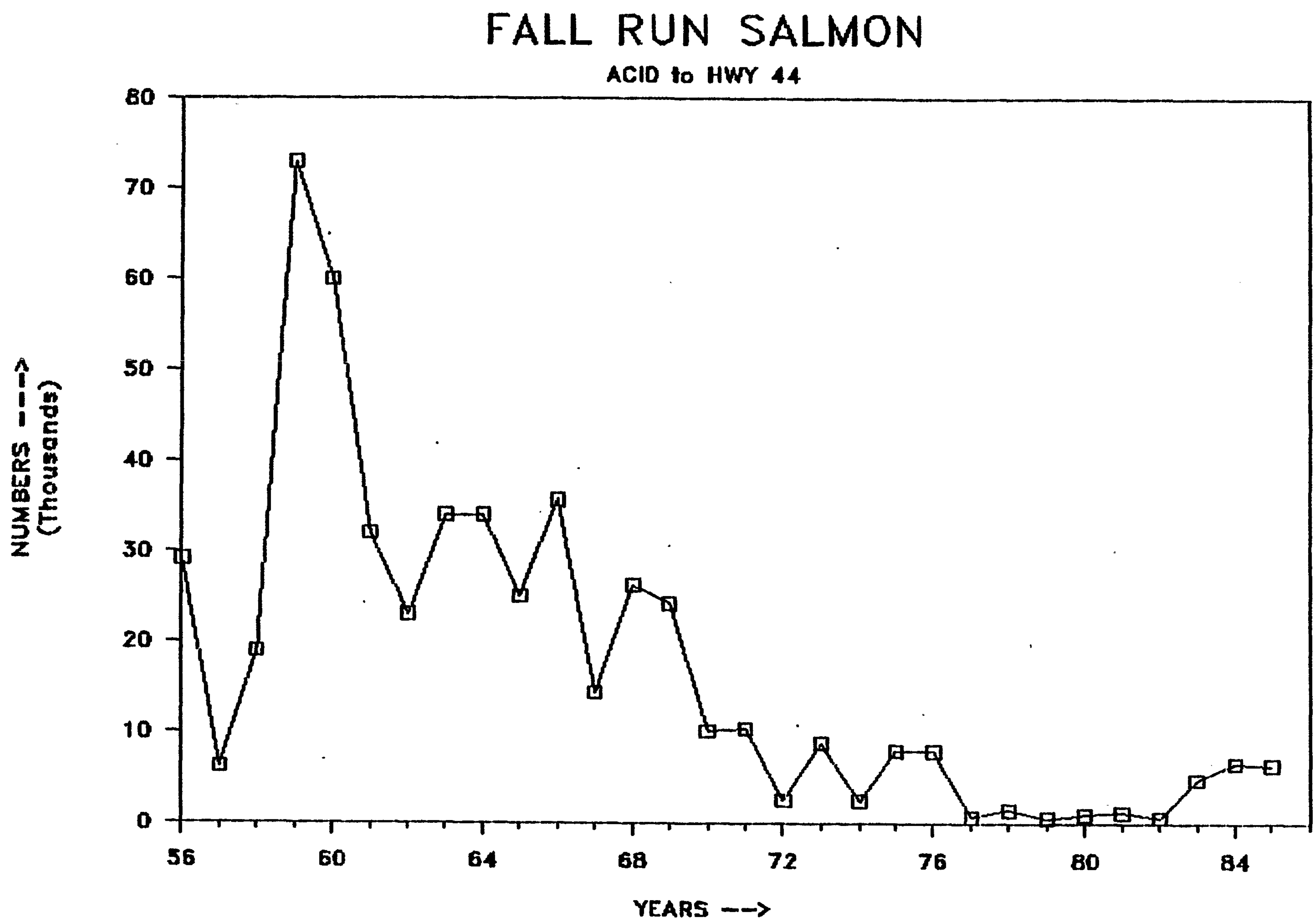

FIGURE 13. Numbers of fall-run salmon that spawn in the Sacramento River between the Anderson-Cottonwood Irrigation District Dam and Highway 44 bridge at Redding.

D-019874

not. It is extremely difficult and costly to quantify the losses, especially since the fish most sensitive to metal toxicity are the "sac fry" in the gravel and the newly emergent 2-inch-long "swim-ups", which are difficult to see or count. Adults are three times more tolerant to copper than the early life stages of salmon. Therefore, in all areas where any adults are killed it would be logical to assume a complete loss of all fry to fingerlings in the area.

Perhaps the greatest number of fish killed by Iron Mountain Mine pollution occurred in 1944, when an estimated one-third of the salmon run died before spawning (DFG, 1953). However, in addition to fish kills, monitoring studies have revealed that significant cadmium, silver and chromium contamination occurs in the resident trout at Redding as well as in Keswick reservoir.

Recommendations

There are at least nine alternative clean-up plans that have been studied by the Environmental Protection Agency for the Iron Mountain hazardous waste site. Perhaps the most positive plan involves control of the toxic materials at the source by concrete plugging and capping (source control). Iron Mountain Mine includes an area of 4,400 acres. It consists of underground workings, an open pit mining area, waste rock dumps and tailings piles. The primary source of contamination is the "orebodies" in the underground workings. Rainfall on the ground above the orebodies infiltrates the underground mine shafts and passes through the ore zones, eventually discharging the acid mine wastes through the access tunnels and through underground seepage. One method of source control, in part, would involve completely capping 15 acres of the ground surface above the principal orebody (Richmond Orebody) with a soil-cement cap to prevent water from reaching the orebody, and thus reduce formation of acid mine drainage.

However, the relative merits of different types of remedial action such as source control, which would eliminate the total quantity of toxic material escaping the mine site, or the current water management plan (control by dilution) should be thoroughly investigated. Source control would be the most positive method; however, if pollution control is to rely on dilution manipulation, a formal agreement to do so should be reached, since the present toxicity control plan is not an authorized purpose of the Shasta Dam Project.

Water Temperature and Flow Fluctuations

Background

Construction and operation of Shasta Dam has drastically altered the flow regime and thermal characteristics of the Sacramento River. Water now released in the spring is often too cold for rapid growth of fall and late fall juvenile salmon, and water released in August and September is often too warm for successful spawning and/or incubation of spring- and winter-run salmon eggs and alevins, especially below Red Bluff. Releases from Shasta also result in abrupt reductions in flow which disrupts salmon spawning, causes losses by dewatering eggs and alevins in the gravel, and strands fry and fingerlings in pools and side channels.

The temperature and flow problem is complicated by the presence of four distinct populations of salmon and one population of steelhead trout. Spawning occurs during every month of the year in the upper Sacramento River. Consequently, optimum water temperatures and flows for spawning, egg incubation, rearing and migration cannot occur concurrently. There is so much overlap in the cycles of these four salmon races, and steelhead, that decisions must be made as to whether to favor one race or seek some type of average benefit.

Flow Agreement

The memorandum of agreement between the U.S. Bureau of Reclamation and the California Department of Fish and Game for the "protection and preservation of fish and wildlife resources of the Sacramento River, as affected by the operation of Shasta and Keswick Dams and their related works and various diversions" (signed April 5, 1960) is probably one of the worst fishery flow agreements in existence, affecting a major California salmon and steelhead stream.

One of the best parts of the agreement states in Article IV that "in the event additional water development projects are constructed by the Bureau, or other parties, on the Sacramento River or its tribuatry streams below Shasta Dam which significantly affect the salmon fishery or the flow regime of the Sacramento River, the terms of this agreement shall be subject to renegotiation". When the Bureau constructed and began operating Red Bluff Diversion Dam and the Tehama-Colusa Canal in 1966, the agreement should have been renegotiated.

The flow schedule agreed upon in Article I of the 1966 agreement follows:

> Article I. The Bureau shall at all times bypass or release into the natural channel of the Sacramento River at Keswick Dam at least the following specified flows for the maintenance of fish and wildlife resources in the Sacramento River except in emergencies or as hereinafter defined:

January 1 through February 28	2600 cfs
March 1 through August 31	2300 cfs
September 1 through November 30	3900 cfs*
December 1 through December 31	2600 cfs

> PROVIDED that during a critical dry calendar year, as hereinafter defined, the minimum flows to be bypassed or released shall not be less than the following:

January 1 through February 28	2000 cfs
March 1 through August 31	2300 cfs
September 1 through November 30	2800 cfs
December 1 through December 31	2000 cfs

> with peaking at least once a day to at least the flows specified for normal years beginning about December 1 and extending to about May 1. In the event of extremely critical conditions during the period December 1 through February 28 the flow may be reduced below 2000 cfs by agreement between the parties.

Some of the most unsatisfactory points in the agreement include:

*An informal agreement between the Bureau and DFG states that a "stable" flow of 3250 cfs will be maintained between September 1 and February 28.

1. The Sacramento River releases to be made during wet, normal and dry years are inadequate (they should never be less than 5,000 to 6,000 cfs); during extremely critical conditions the agreement flows may be reduced even more (to some unspecified amount less than 2,000 cfs) but with no attempt to make all users take equal reductions. Even during a critical dry year, the flows should never be less than 4,500 cfs.

2. Article I states that, "releases of water from Keswick Dam during the period September 1 through December 31 will be made with a minimum of fluctuation or change "to the extent that it is compatible with other operational requirements"; there is no attempt in the agreement to minimize fluctuations during the rest of the year, nor is there anything specific as to how great the fluctuations can be. Furthermore, the agreement does not say that the Bureau has to do anything relative to fluctuation if it does not want to; i.e, if they say that non-fluctuating releases are not compatible with other operational requirements, they can forget about it.

3. The agreement does not even mention the temperature of the water to be released; it only includes minimum flows to be released. The high temperature of flows released in 1977 destroyed the entire winter-run salmon production.

Temperature

Existing water demands have resulted in releases, from the Shasta-Keswick Dam complex, of high temperature water during the fall and summer spawning period for salmon which has caused serious losses. This occurs primarily during years of low precipitation and when storage is low in Shasta and Clair Engle Reservoirs, such as 1959, '61, '64, '68, '76, '77, and '85. It is anticipated that by the year 2020, because of increased demands for water, Shasta Dam operation and flow releases will cause low reservoir storage levels and high temperature water releases to occur as they do now only in dry years. This will then become the norm rather than the exception.

The optimum growth and incubation temperature for salmon is about 54 degrees Fahrenheit (Table 2). By 2020, the average temperature of fall Keswick Dam releases will probably be in the 60's, and anadromous fish mortality will be high at these temperatures.

Unless a solution to the temperature problem is found, most (if not all) of the winter- and spring-run salmon that spawn in the Sacramento River will probably be eliminated under the anticipated year 2020 conditions. The Bureau of Reclamation-sponsored Central Valley Fish and Wildlife Management Study is now addressing the problem. A draft report has been prepared, but feasibility studies have not been initiated.

Recommendations

Of the present proposed alternatives to solve the temperature problem, the benefits to be derived from a temperature control structure at Shasta Dam coupled with cold water releases from the Trinity River system would be greatest in reducing existing losses, and may also be the best solution to reducing losses under the year 2020 level operations. The estimated cost of implementing this alternative would be about $7.8 million: structural costs $3.1 million, and annual power loss $4.7 million.

Life stage	Temperature (°F) Preferred range	Optimum
Spawning	42 - 57 1/	
Incubation	43 - 58 2/	
Juvenile rearing	45 - 58 1/	54
Adult migration: 3/		
a. general	49 - 57.5	
b. fall	51 - 67	
c. spring	38 - 56	

1/ Reiser and Bjornn, 1979 2/ Healey, 1979 3/ Bell, 1984

Table 2. General temperature ranges (°F) and optimum values for selected stages of the chinook salmon life cycle.

Flow Fluctuations

Abrupt changes in releases from Shasta Dam, primarily to meet irrigation demands, is a major problem that is limiting salmon production in the Sacramento River. Sudden reductions in flows disrupts salmon spawning, causes losses by dewatering eggs and alevins in the gravel, and strands fry and fingerlings in pools and side channels. These flow reductions have been noted, but to date the total losses have not been quantified. Nevertheless the losses are known to be considerable at times in the limited areas observed, especially those resulting from dewatered redds.

Recommendation

The present DFG upper Sacramento River instream flow study (scheduled for completion in 1989) should provide data upon which to base a much needed flow agreement for releases from the Shasta-Keswick Dam complex into the Sacramento River. The agreement should be specific to and spell out the flows and temperatures that need to be provided; it should also address the flow fluctuation problem. Fishery needs are as legitimate as agricultural needs and must be seen as equally important.

Gravel Recruitment and Bank Riprap

Lack of a source of spawning gravel recruitment is a major problem that has contributed significantly to the decline of salmon runs in the Sacramento River between Keswick Dam and Balls Ferry. It will also become a major problem downstream from Red Bluff if unlimited bank protection, using rock riprap, is permitted to take place.

Prior to construction of Shasta and Keswick Dams, 30% of the spawning gravel in the Sacramento River between Redding and Balls Ferry originated above Keswick Dam. In the Redding-Balls Ferry area many of the formerly excellent spawning riffles are now nearly unusable because they have become armored with 12-inch diameter rocks; the suitable spawning gravels have been washed downstream and there is now no source of gravel recruitment. This is particularly noticeable in the Redding area. In a recent experimental effort to alleviate this problem, DFG has replaced some of the gravel in the Redding area, and as an alternative has also developed side channels to provide increased suitable spawning area. Several limitations immediately became apparent: the job is a very massive one; the time windows when work can be done are extremely narrow, and winter flows soon wash out the artificially emplaced gravels.

Studies by the California Department of Water Resources indicate that 85% of the spawning gravel in the Sacramento River downstream from Red Bluff comes from bank erosion; the rest comes from the tributaries. Fortunately, recent plans by the U.S. Corps of Army Engineers and the State Reclamation Board to riprap 40% of the Sacramento River banks between Chico Landing and Red Bluff have been stopped, at least for the time being. The first obstacle to this plan developed when state funding for the project was tied up due to the Corps of Engineers and the State Reclamation Board being unable to develop mitigation measures, required by state law, that would adequately protect the fish, wildlife, riparian habitat and endangered species values of the river. The apparent final blow to the riprap project occurred when FWS invoked the Federal Endangered Species Act to halt the riprap project in view of the presence in the affected area of the threatened elderberry longhorn beetle.

Recommendations

As an alternative to rock riprap, other measures should be considered, including set back levees, and especially the public purchase and ownership of the ± 100-year Sacramento River meander belt, to allow the river to meander naturally.

Legislation should be passed which would give control of gravel in designated salmon and steelhead spawning streams, as well as in streams which contribute gravel to salmon and steelhead spawning streams, to DFG. Lacking such legislation, county ordinances should prohibit gravel mining in salmon and steelhead spawning streams as well as streams contributing gravel to such spawning streams.

The State of California, and counties along the Sacramento River, should adopt policies preventing encroachment on the flood plain and the ± 100-year meander belt of the Sacramento River.

To guarantee future supplies, a gravel monitoring program should be initiated relative to salmon and steelhead spawning areas to document changes and to assure that needed corrections are made.

Anderson-Cottonwood Irrigation District Dam

Description

The Anderson-Cottonwood Irrigation District (ACID) diversion dam is a removable stoplog, or flashboard, type dam located on the Sacramento River at Redding. It is constructed of concrete, with a steel superstructure. Between the two abutments there are 69 concrete piers on which collapsible steel A-frames are mounted to support wooden stoplogs. When the dam is in place, about 400 cfs of water is normally diverted into the ACID canal, which heads at the right bank dam abutment. The flashboards, which may raise the dam to a maximum vertical height of approximately 12 feet, are installed during the irrigation season, which is normally from April through October, and is within the legally prescribed operation dates of March 15 and December 1.

Problems

There are presently two major fishery problems associated with the ACID dam: (1) river flow reductions necessary to install and remove flashboards, and (2) fish passage at a very inefficient fish ladder on the left bank abutment.

Losses of salmon caused by flow reductions to install and remove ACID dam have not been well monitored or documented. However, considerable salmon losses were recorded in the fall of 1969, when flows were reduced to remove the dam. At that time it was reported by DFG that substantial numbers of adult salmon as well as thousands of juvenile salmon were lost. However, since that time, reported losses have been considerably less. Losses relative to installing and removing the dam have been somewhat alleviated because flows are now reduced according to an informal schedule developed by DFG.

Adult fish passage, when the dam is in place, is a problem due to the crooked configuration and extremely narrow width of the fish ladder, as well as the lack of adequate attraction flows to the ladder. The fish ladder

D-019880

has a capacity of only 30 cfs. Salmon which are successful in passing ACID dam normally spawn in the 3½ miles of Sacramento River between ACID dam and Keswick Dam, or are collected in the fish trap at Keswick Dam and transported to Coleman National Fish Hatchery (CNFH) for artificial spawning. In 1985, redd distribution of spawning salmon in the main stem of the Sacramento River indicated that 25% of the late fall-, 6% of the winter- and 11% of the fall-run salmon spawned between Keswick and ACID dams.

Lake Redding Power Plant

A potential future problem at ACID dam is the proposed Lake Redding Power Plant. The City of Redding has obtained preliminary permits from the Federal Energy Regulatory Commission (FERC) to construct, own and operate the Lake Redding Power Plant at the site of ACID dam. The estimated cost of the power plant is $115 million. The key features of the project are Redding Diversion Dam (near the site of the present ACID dam) and Lake Redding Power Plant. Lake Redding Diversion Dam would be located 30 feet downstream from, and would replace, ACID dam. The proposed dam would provide water diversions to the ACID canal identical to existing diversions. A major difference between ACID dam and the proposed Lake Redding Diversion Dam is that the proposed dam would remain in place year around. The power plant would have a maximum flow capacity of 15,000 cfs.

The Lake Redding Power Project presents many potential fish-related problems that need to be addressed before it is accepted. Some of these problems include fish passage, loss of spawning gravel upstream from the dam due to inundation, mortality related to seaward migrant juveniles passing through the power plant turbines, and changes in habitat which could favor conditions for Sacramento squawfish, or other predatory fish, immediately downstream from the project.

Recommendations

If ACID dam is to continue operating as it does today, a new fish ladder should be constructed. The fish ladder should include a fish trapping facility to enable regulating the numbers of salmon that utilize the area between ACID dam and Keswick Dam, as well as to facilitate transporting salmon to CNFH. A fish trap at ACID would have the additional advantages of reducing stress and potential adult salmon mortality by decreasing the hauling time to CNFH (as compared to the hauling time from the Keswick Dam fish trap). Either an efficient fish ladder or a fish trap at ACID dam is also essential to assure that CNFH meets its new goals for propagating winter- and spring-run salmon.

The agreement relative to flow reductions to install or remove ACID dam should be formalized.

If Lake Redding Power Project is constructed, and studies reveal that habitat between ACID dam and Keswick Dam is now degraded, mitigation should include construction of a fish trapping facility as part of the permanent Lake Redding Diversion Dam. In addition, mitigation should include improvement of the habitat downstream from the Lake Redding Diversion Dam (to make up for lost habitat) and a hatchery or off-stream spawning channel. If Lake Redding Diversion Dam is not to be a total barrier to adult fish, new fish ladders should be included at the dam, as well as positive fish screens to prevent juvenile salmonid losses in the power plant turbines and irrigation canal.

Coleman National Fish Hatchery and Keswick Fish Trap

Background

When Shasta Dam and its downstream regulatory dam, Keswick Dam, were constructed by the U.S. Bureau of Reclamation, they blocked salmon and steelhead from reaching about 50% of the remaining Sacramento River system spawning grounds. To compensate for this loss of spawning area and for anticipated fish losses, a "Shasta Salvage Plan" was adopted by the Bureau of Reclamation. It had the apparent blessings of FWS and DFG. The plan included only mitigation for fall- and spring-run salmon, none for late-fall and winter-run salmon or for steelhead. Only part of the plan was ever implemented. As each element of the salvage plan failed, it was simply abandoned and those particular groups of fish to be salvaged were just "written off". The only elements of the original salvage plan still remaining (since 1946) are CNFH and the fish trapping facility at Keswick Dam. The fish trap was designed to transfer spring-run salmon to CNFH and Battle Creek. However, since CNFH could not handle spring-run salmon successfully (primarily because of high water temperatures) Keswick has been operated through the years to supplement the numbers of fall-run salmon, and some late fall-run salmon and steelhead, that enter Coleman Hatchery via Battle Creek.

Coleman National Fish Hatchery

Coleman National Fish Hatchery first became operable in 1943. By 1949 the Bureau of Reclamation transferred custody and funding of CNFH to the FWS. The first eggs were not taken, and juveniles reared, until 1946.

Present Production

Current salmon production objectives include 12 million fall-run salmon at 90/lb., 2 million late fall-run at 40/lb., and 1 million steelhead trout at 7/lb. The annual operating budget is about $570,000 (1983).

Plans To Increase Production

There are currently two plans to increase production at CNFH: (1) an emergency program already funded at $2.2 million, to be undertaken immediately, for restoration of winter-run salmon in the upper Sacramento River, and (2) a proposed development plan with a projected cost of $6.4 million, which would upgrade the hatchery facilities and increase production by 2.9 million salmon smolts and 300,000 yearling steelhead. Production would include salmon from all four races. This development plan could annually contribute (over present production) an additional 30,000 salmon to the ocean sport and commercial fisheries as well as 3,000 adult steelhead to the Sacramento River runs (Table 3).

Disease Policy

The U. S. Fish and Wildlife Service's Fish Health Protection Policy and Salmonid Fish Health Protection Program (May 30, 1984) states that "In the event whirling disease (fish infected by the protozoan Myxosoma Cerebralis) is confirmed at a service facility which extends the known range of the disease, immediate steps to eradicate whirling disease from the station and from adjacent waters shall be initiated upon authorization by the Regional Director and concurrence of the involved state(s)." The policy further states that "in the event whirling disease outbreaks occur at service facilities, within the known range of the disease, conservation agencies and concerned parties shall be notified of the circumstances and consulted with to

Run	Present Production	Development Plan (1983) Production	Change
Fall	12,000,000	11,000,000	-1,000,000
Late Fall	2,000,000	1,400,000	- 600,000
Winter		2,000,000	+2,000,000
Spring		2,500,000	+2,500,000
	14,000,000	16,900,000	+2,900,000
Steelhead	1,000,000	1,300,000	+ 300,000

Table 3. Coleman National Fish Hatchery, present and proposed production.

determine a course of action that will maximize benefits to the fishery resources." The disease policy further states that, "in the event PKD (proliferative kidney disease) is confirmed in any salmonid stock under propagation at a service facility, immediate steps shall be initiated to eradicate this disease from the facility and from the adjacent waters."

This fish disease policy is a major obstacle to maintaining or enhancing Sacramento River salmon and steelhead populations involving Coleman Hatchery reared fish. If the policy were ever followed to the letter, it could result in complete destruction of all production each time whirling disease or PKD were detected at the facility. Such an event would reduce the Sacramento River steelhead fishery by 70% and the ocean sport and commercial salmon fisheries by 120,000 to 180,000 fish. In 1986, the FWS disregarded the fact that whirling disease had already been confirmed in the Sacramento River system and the Klamath River system, as well as in the Columbia River system: they destroyed 1.3 million yearling steelhead at CNFH (reared at a cost of more than $400,000) because whirling disease was detected among less than one percent of the fish on hand. There were no steelhead losses at the hatchery attributed to the disease. The disease is not harmful to man, nor is PDK. Destroying the steelhead has had a catastrophic effect on the upper Sacramento River steelhead fishery, since CNFH provides 70% of the run and catch.

Predation by Released Steelhead

Yearling steelhead released from CNFH into Battle Creek in February and March destroy large numbers of naturally produced salmon fry as they emerge from the gravels downstream from the hatchery. For example, more than 600,000 yearlings were released during February and March of 1975, and sampling of these steelhead in Battle Creek indicated they averaged 1.4 juvenile salmon per steelhead stomach. Had each of the 600,000 yearlings eaten only one salmon before leaving Battle Creek, the loss would have been more than one-half million fry. This is undoubtedly a conservative number; as one biologist put it, the yearling steelhead "practically sterilized" the stream.

The same type of predation problem was noted in the Feather River after Feather River hatchery yearling salmon were released in the Feather River, and sampling demonstrated that the salmon yearlings had consumed several million naturally produced juvenile salmon before migration out of the Feather River.

Recommendations

Keswick fish trap operates efficiently only up to flows of 16,000 cfs. It should be modified so trapping would be efficient up to flows of 55,000 cfs, assuring efficient functioning for all four races of salmon as well as steelhead trout.

At CNFH many of the structures and facilities were constructed in 1942 and are now antiquated. The proposed 1983 development plan ($6.4 million) should be expanded, funded and implemented as a single stage development. The $2.2 million emergency program for winter-run salmon restoration should be implemented immediately.

The U.S. Bureau of Reclamation, the agency which has caused the problem for which CNFH is mitigating, should be made responsible for funding CNFH. CNFH should be funded at a range between $1 million and $1.5 million annually instead of the current $570,000.

CNFH salmon production should be released below RBDD if the dam gates are down, or during periods of coordinated increased flow releases from Shasta Dam, made specificially for that purpose. Salmon should not be released when the Sutter and Yolo bypasses are flooding.

The Federal Fish Disease Policy should be revised so that salmonids, among which whirling disease or PKD has been detected, will normally be released. This would apply to all Federal facilities in the Sacramento system. Downgrading these diseases, as recommended by DFG, would provide a more realistic policy . Efforts to reduce losses from IHN (Sacramento River chinook disease) should also be increased.

The DFG has the ultimate responsibility for salmon and steelhead management in California, and should have control over all salmon and steelhead production (including CNFH) which affects the populations and fisheries they are responsible for.

Accordingly, CNFH should continue to be funded by the Federal Government, but it should be managed by DFG (as Trinity River and Nimbus Hatcheries are). However, because of the excellent FWS staff at CNFH it would be highly desirable to maintain that staff intact and simply have the facility operate under DFG policy rather than FWS policy.

Red Bluff Diversion Dam

Description

One of the major causes, and perhaps the single most important recent cause of the decline of salmon and steelhead in the Sacramento River is Red Bluff Diversion Dam (RBDD). Completed in 1964, RBDD is located on the Sacramento River two miles downstream from Red Bluff. It was constructed and is operated by the U.S. Bureau of Reclamation to divert water from the Sacramento River into the Tehama-Colusa Canal (which includes the Tehama-Colusa Fish Facilities) and to the Corning Canal Pumping Plant. During an average water year 700,000 acre feet of water is diverted into the TCC and an additional 50,000 acre feet is diverted into the Corning Canal. The diversion headworks are near the right bank abutment and include a louver type fish screen to prevent fish in the river from entering the canals. The dam has a crest length of 752 feet. Sacramento River water levels are contolled by 11 dam gates, each 60 feet wide and 18 feet high. Water is released by raising one or more gates. A fishway, with facilities to count adult salmon and steelhead (closed circuit television) is located on each dam abutment. A fish trap is incorporated into the left bank fishway where adult salmon and steelhead can be examined and released, or selected for transfer to the Tehama-Colusa Fish Facilities spawning channels (or to other locations).

Spawning Distribution Changes

Starting shortly after RBDD was put into full operation in 1966, several changes occurred in the distribution and numbers of fall-run salmon in the upper Sacramento River system. The numbers of salmon that spawned above the dam have declined sharply, while the salmon spawning below have gradually increased from less than 10% of the total to more than 60% by 1977, and in 1985 still made up more than 25% of the total (Figure 14, Table 4).

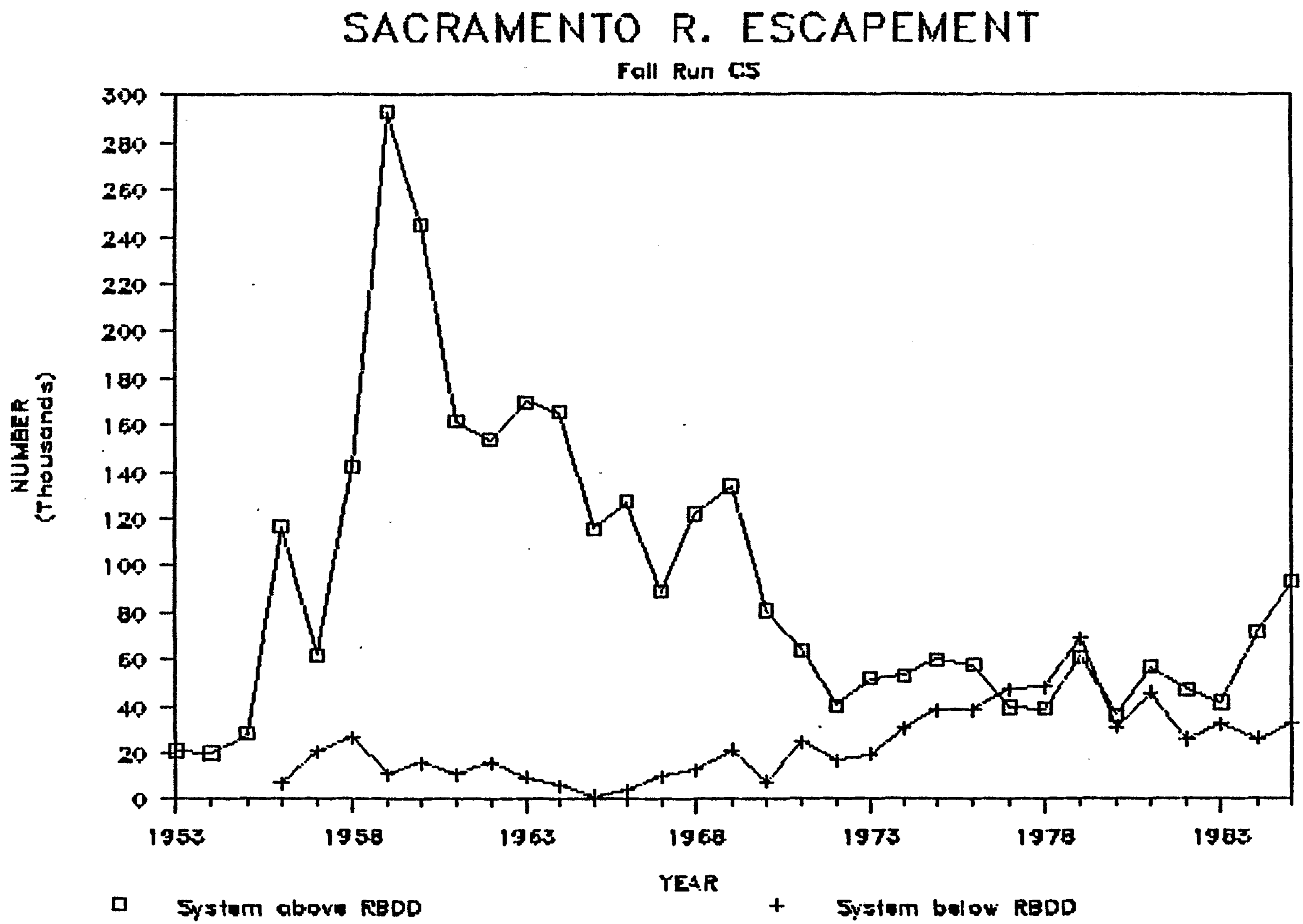

FIGURE 14. A comparison between the total fall-run salmon spawning populations in the Sacramento River system above Red Bluff (line with square symbols) and the total fall-run salmon spawning populations in the Sacramento River system below Red Bluff (above the mouth of the Feather River) (line with plus symbols).

	******* Above RBDD			**************		*****Below RD	******		
Year	Main Stem	Coleman	Battle Cr.	Other Tribs.	System Above	Main Stem	Other Tribs.	System Below	System Total
1953		12000	4000	5000	21000				
1954		8000	4000	8000	20000				
1955		10000	16000	2000	28000				
1956	87357	7458	13650	7850	116315	5800	1353	7153	123468
1957	54989	3045	2285	1568	61887	12200	8449	20649	82536
1958	107153	14643	14600	5930	142326	20600	6040	26640	168966
1959	256700	10833	19400	5771	292704	9900	847	10747	303451
1960	218940	9605	14200	1960	244705	14000	1990	15990	260695
1961	140181	8156	11700	1500	161537	9400	1689	11089	172626
1962	127837	4857	8200	12900	153794	8500	7184	15684	169478
1963	138881	5114	12400	13500	169895	6800	2835	9635	179530
1964	142584	3875	12000	7000	165459	5500	600	6100	171559
1965	101876	3194	6000	4785	115855	1500	410	1910	117765
1966	111881	900	2400	12100	127281	3100	800	3900	131181
1967	82490	3050	2160	1520	89220	9200	620	9820	99040
1968	98429	3526	2950	17190	122095	11800	1100	12900	134995
1969	115652	2626	3200	13337	134815	17600	2690	20290	155105
1970	68794	3512	3320	5308	80934	5860	1590	7450	88384
1971	53888	2004	3285		59177	23215	6889	30104	89281
972	33958	2822	2030		38810	15460	3451	18911	57721
1973	41129	3835	4300		49264	17485	4163	21648	70912
1974	47019	1607	2294		50920	27970	4758	32728	83648
1975	53129	2431	2426		57986	36194	5199	41393	99379
1976	45761	2297	3147	4333	55538	37530	3322	40852	96390
1977	16176	5244	5604	2874	29898	45743	4802	50545	80443
1978	32235	1882	1770	1180	37067	47973	2495	50468	87535
1979	47758	8729	4430		60917	67388	1643	69031	129948
1980	21961	9503	4940		36404	30278	856	31134	67538
1981	29212	10272	6933	7028	53445	42724	2907	45631	99076
1982	17966	19525	7270	1515	46276	23833	2082	25915	72191
1983	26226	8756	5227	1100	41309	30751	3507	34258	75567
1984	36965	21581	8312	4840	71698	19166	7150	26316	98014
1985	51647	16320	23961	700	92628	27873	5205	33078	125706

Table 4. Numbers of fall-run salmon spawning in the Sacramento River system, above the mouth of the Feather River.

This is not just a redistribution of salmon utilizing the two spawning areas where the total number has remained constant, since a large number of salmon are now missing, all from those that spawned above the dam.

Problems

The problems at RBDD are primarily related to passage of both adult and juvenile salmonids. Adult salmon are delayed below the dam from 1 to 40 days, and more than 26% that approach the dam never pass (Table 5). Delay time, which adversely affects spawning success, increases with increases in flow, since the adult fish have more difficulty finding the fishways at higher flows (Figure 15, Table 6) (Hallock, Vogel & Reisenbichler 1982). Survival of juvenile salmonids that do not have to pass the dam on their way to the sea is greater than those that do: fingerling salmon 46% greater and yearling steelhead 25% greater (Table 7).

Fish losses specific to RBDD are caused in part by (1) inadequate attraction flows from the fishways, which result in delay and blockage of adults, and (2) turbulence immediately below the dam which disorients both juvenile and adult salmonids; in particular, the juveniles are thrown to the surface where they become easy prey for predatory fishes, especially Sacramento River Squawfish. Other documented losses of juveniles result from a very inefficient fish screen at the headworks of the Tehama-Colusa, Corning Canal intake.

Fish Losses

Historical data are lacking for all but fall-run salmon, resulting in less accuracy in estimating the effect of RBDD on late fall-, winter- and spring-run salmon, as well as steelhead. However, between 1969 and 1982, RBDD has caused an estimated loss in upper Sacramento River system salmon populations of 114,000 fish; 57,000 fall-; 17,000 late fall-, and 40,000 winter-run. These losses have deprived the fisheries of about 228,000 salmon a year, at a catch to escapement ratio of two-to-one. The fall-run salmon loss figures are in agreement with Reisenbichler (1982) who estimates that solving the problems at RBDD would return the fall-run salmon population to the 1955-65 levels (Figures 16-19 and Tables 8-11).

In addition, RBDD has caused an estimated decline of 6,000 sea-run steelhead in the upper Sacramento (Figure 20 and Table 12).

Ripe Salmon Handled

During DFG fish trapping operations at RBDD, to separate the total closed circuit TV counts into the various runs and to look for marked and/or tagged fish, about 1,400 ripe female salmon (losing eggs when handled) with an estimated average potential of 7 million eggs are handled annually (Table 13). At present, these fish are released in hopes that they will eventually spawn successfully. However, until studies show that fish in this condition do spawn successfully in the river if released, it is recommended that they be spawned artificially and the eggs incubated to hatching and preferably that the fry be reared prior to release.

The FWS has already constructed a 3 million egg capacity incubation station for this purpose near RBDD left bank fishway. It became operational in 1979, but has never been used for this purpose to date, primarily because of lack of personnel and management interest. The handling of 7 million eggs in this facility could add between 7,000 and 30,000 fish to the ocean catch, depending upon their size when released. This procedure could also

Run	Delay time of fish blocked (days)	Delay time of fish not blocked (days)	Estimated Effect[1/] Relative	Reason
Late Fall	30.0	Av. 3.9 (Rn 1-7)	1	Delay of ripe fish
Fall	14.3	Av. 3.5 (Rn 1-15)	3	Delay of ripe fish, Crowded spawning area below dam.
Spring	33.3	Av. 11 (Rn 1-22)	5	Delay of ripe fish. High summer temp. below Red Bluff
Winter	37.5	Av. 18.2 (Rn 1-40)	10	High spawning temps., some years below Red Bluff.

1/ On a scale of 1 to 10.

Table 5. Red Bluff Diversion Dam Blockage and Delay of Adult Salmon.

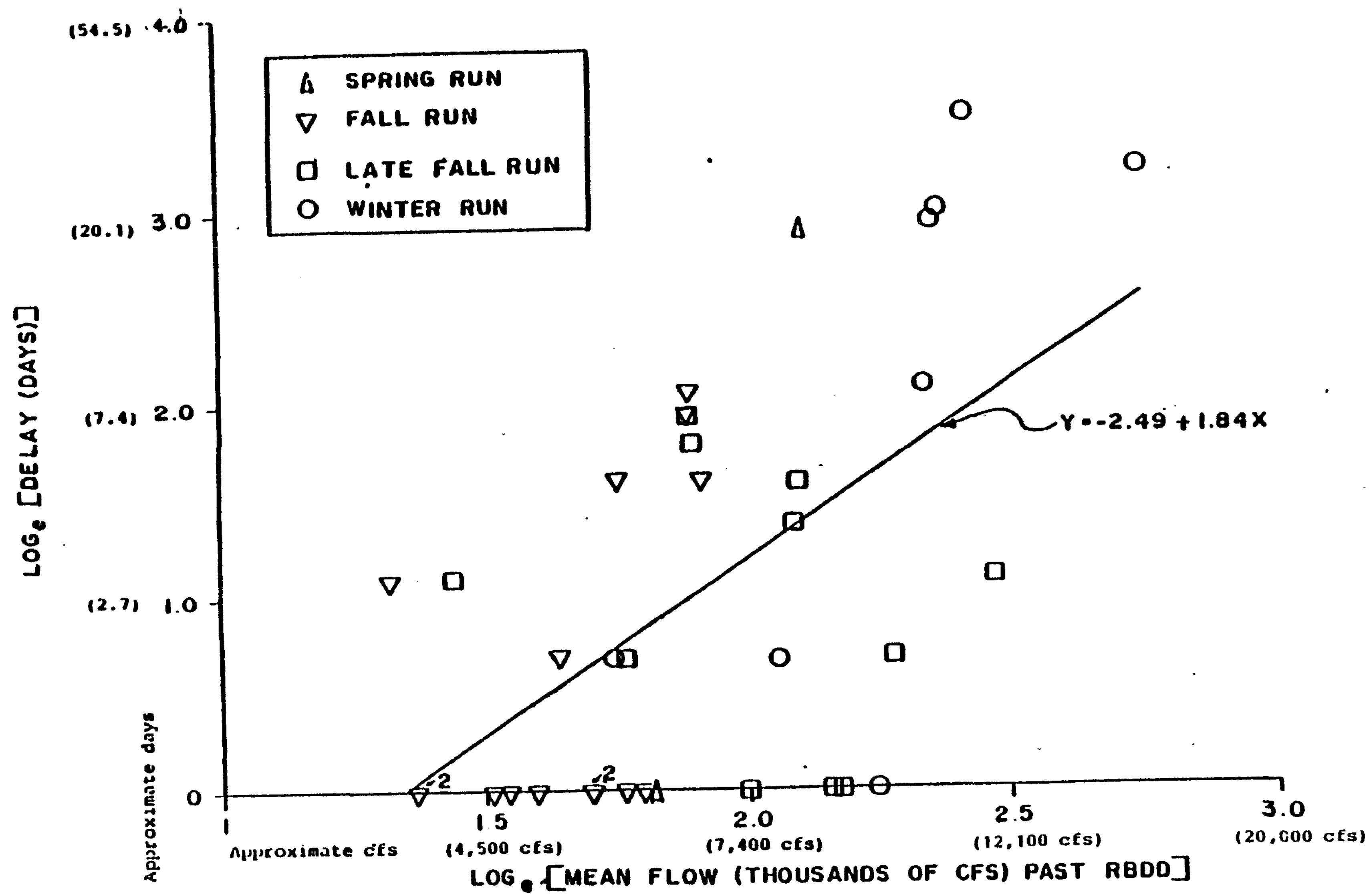

FIGURE 15. Relationship between delay (in Area One) of radio tagged salmon that passed Red Bluff Diversion Dam (RBDD) and mean flow (all data transformed to natural logarithms). From: Hallock, R.J., D.A. Vogel and R.R. Reisenbichler, 1982.

Year	January	February	March	April	May
1967	17,240	23,220	9,882	19,760	19,600
1968	11,940	24,240	13,830	9,606	9,763
1969	34,030	39,990	14,280	11,840	16,090
1970	61,060	38,870	12,760	9,465	9,520
1971	25,820	14,080	11,780	16,520	17,190
1972	8,909	9,750	14,350	10,950	11,140
1973	30,140	28,440	17,320	9,187	11,220
1974	52,860	22,180	29,830	35,110	14,860
1975	8,186	19,860	29,760	13,710	16,710
1976	7,335	9,129	8,447	11,060	12,790
1977	6,693	6,117	6,390	8,442	8,330
1978	21,550	17,800	27,380	15,880	11,060
1979	8,897	10,370	8,291	8,133	9,386
1980	26,190	36,220	23,350	8,849	8,623
1981	9,791	9,273	12,930	9,977	12,120
1982 1/	22,240	32,200	22,000	29,790	15,720
1983 1/	23,920	58,190	75,830	22,910	22,510
Average	22,164	23,525	19,906	14,776	12,743

1/ Preliminary

Table 6. Average monthly flow of the Sacramento River near Red Bluff (cubic feet per second).

D-019891

Release Area	(on going study) Late-Fall-Run Salmon					(on going study) Fall-Run Salmon			(completed study) Fall-Run Salmon				(completed study) Steelhead	
	Returns by Release Year					Returns by Release Year			Returns by Release Year				Returns by Release Year	
Release Year	1979	1980	1981	1982	Totals	1981	1982 1/	Totals	1975	1976	1977	Totals	1973-75	Total
Battle Creek	197	592	183	37	1,009	184	11	195						273
2 mi. above Dam									91	95	39	225		
Above Dam gate										111	148	259		
Below Dam gate										145	242	387		
¼ mi. below Dam	283	814	332	45	1,474	364	6	370	546		39	495		372

1/ Two-year old fish only.

2/ Marked salmon recovered in the ocean fishery landings of California, Oregon, and Washington and marked adult steelhead recoveries at Coleman Hatchery.

SUMMARY				
Species	Total Released		Survival	Increase in suvival by Releasing below the Dam
Salmon	above Dam	1,257,654	1,688 (.13%)	46%
	below Dam	1,134,934	2,726 (.24%)	
Steelhead	above Dam	301,948	273 (.09%)	25%
	below Dam	302,864	372 (.12%)	

Table 7. Survival 2/ of salmon released above and below Red Bluff Diversion Dam Data from DFG (unpublished).

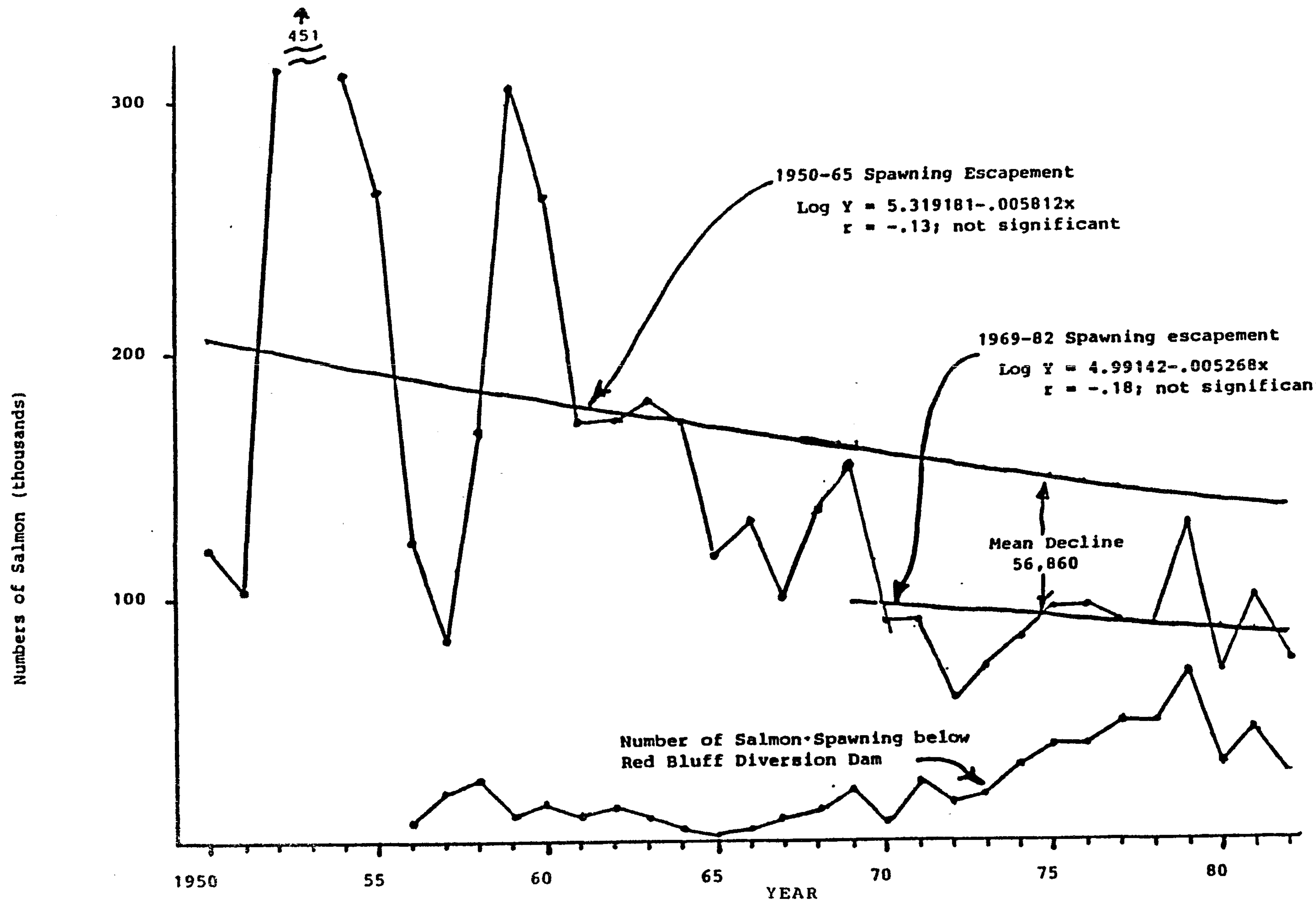

FIGURE 16. This is the calculated regression for the numbers in Table 8. They show a total decline of 56,860 (39%). The regressions are not significant. The 1950-65 regression line has been extended to 1982 in order to estimate what would have happened to the population had the dam not been constructed. The 1969-82 regression line shows what actually happened to the population after the dam was constructed. The difference between values of the two regression lines during the 1969-82 period represents the loss attributable to the dam.

D-019893

FALL-RUN SALMON

Averages

Years	Ex	N		Mean Population
1950-65	3,312,538	16		207,034
1969-82	1,301,865	14		92,990
			Declines	-114,044(-55%)

Regression

1950-65		1969-82	
Log Y = 5.319181-0.005812		Log Y = 4.9914121-0.005268x	
	Calculated Population	Calculated Population	Net Decline
1969	159,566	96,861	-62,705
1970	157,444	95,694	-61,750
1971	155,352	94,540	-60,812
1972	153,287	93,400	-59,887
1973	151,249	92,274	-58,975
1974	149,238	91,162	-58,076
1975	147,254	90,063	-57,191
1976	145,269	88,977	-56,320
1977	143,366	87,904	-55,462
1978	141,459	86,844	-54,615
1979	139,579	85,797	-53,782
1980	137,723	84,763	-52,960
1981	135,892	83,741	-52,151
1982	134,086	82,730	-51,356

1969-82	Extropolated	146,485
1969-82	Regression	89,625
	Decline	-56,860(-39%)

Table 8. This is a comparison between the 1950-65 average upper Sacramento River system spawning population (Red Bluff Diversion began operating in 1966), and the 1969-82 average spawning population. It indicates a total decline of 114,044 (55%) during the 1969-82 period.

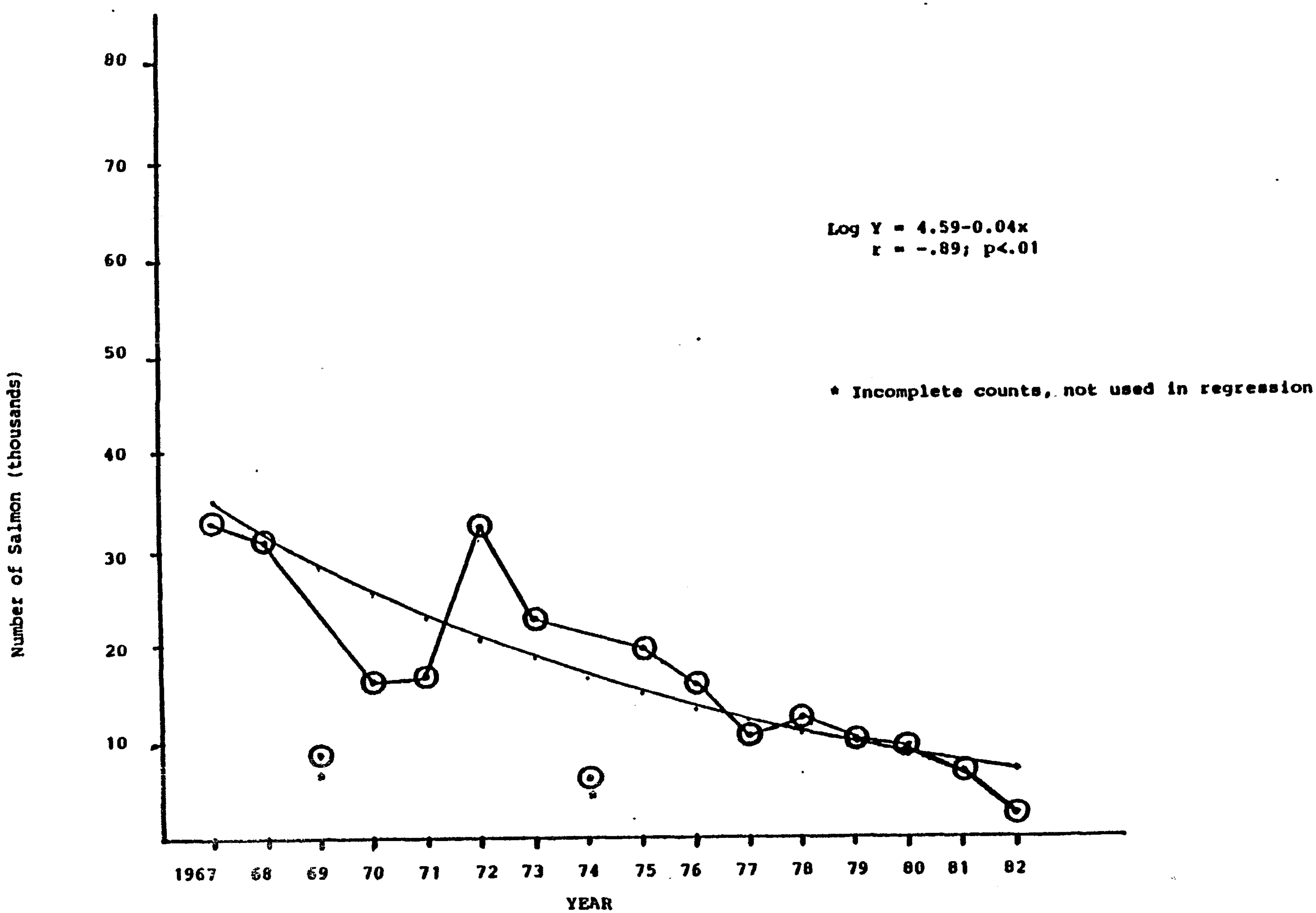

FIGURE 17. This is the calculated regression for numbers appearing in Table 9. The 1967-69 average salmon count past Red Bluff is compared with the 1970-82 average count. The difference between values of the regression averages indicates a total decline of 17,223 (54%), or 28% per generation. This regression is significant.

LATE-FALL-RUN SALMON

Averages

Years	Ex	N	Mean Population
1967-68	63,887	2	31,943
1970-73, 75-82	179,613	12	14,968
		Decline	-16,975 (-53%)

Regression

Log Y = 4.592873-0.046613; r = .-89

Year	Calculated Population		Decline per Generation Number	Percent
1967	35,177	x		
1968	31,597	one		
1969	28,381	Generation		
1970	25,493	x	9,684	28
1971	22,898		8,699	28
1972	20,568		7,813	28
1973	18,475		7,018	28
1974	16,595		6,303	28
1975	14,906		5,662	28
1976	13,389		5,086	28
1977	12,026		4,569	28
1978	10,802		4,104	28
1979	9,703		3,686	28
1980	8,716		3,310	28
1981	7,828		2,974	28
1982	7,031		2,674	28

Year	Ex	N	Mean Population
1967-69	95,155	3	31,718
1970-82	188,430	13	14,495
		Decline	-17,223 (-54%)

Table 9. This is a comparison between the 1967-68 average adult salmon count past Red Bluff, and the 1970-73, 75-82 average count. It shows a total decline of 16,975 (53%).

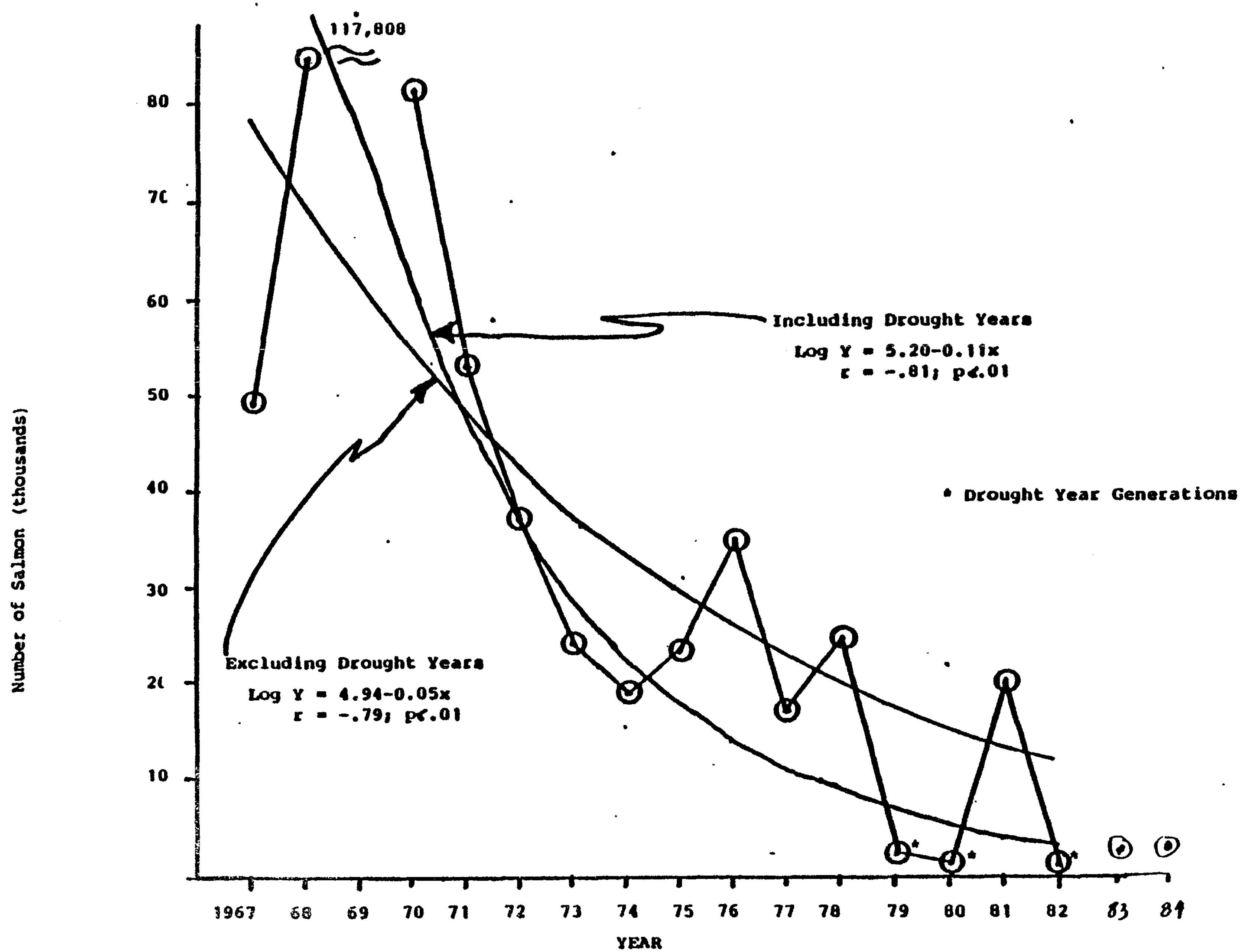

FIGURE 18. These are the calculated regressions for numbers appearing in Table 10. The 1967-69 average salmon count past Red Bluff is compared with the 1970-82 average count. The regression line values show a decline of 40,364 (58%) if the drought years are excluded, or 30% per generation. If the drought years are included, the decline is 79,289 (79%) or 52% per generation. [redacted]se [redacted]essi[redacted] a[redacted]ign[redacted]cant

WINTER-RUN SALMON (adjusted counts)

Averages

Including Drought Year Generations

Year	Ex	N	Mean Population
1967-69	251,775	3	83,925
1970-82	338,981	13	26,075
		Decline	-57,850 (-69%)

Excluding Drought Year Generations

Year	Ex	N	Mean Population
1967-69	271,775	3	83,925
1970-78,81	335,218	10	33,522
		Decline	-50,403 (-60%)

Regression

Including Drought Year Generations

$\text{Log } Y = 5.201689 - 0.105060x; \; r = -.81$

Year	Calculated Population		Decline per Generation Number	Percent
1967	124,919	x		
1968	98,078	one		
1969	77,003	Generation		
1970	60,457	x	64,462	52
1971	47,467		50,611	52
1972	37,267		39,736	52
1973	29,260		31,197	52
1974	22,972		24,495	52
1975	18,036		19,231	52
1976	14,161		15,099	52
1977	11,118		11,354	52
1978	8,729		9,307	52
1979	6,853		7,308	52
1980	5,381		5,737	52
1081	4,224		4,505	52
1982	3,317		3,536	52

Year	Ex	N	Mean Population
1967-69	300,000	3	100,000
1970-82	269,243	13	20,711
		Decline	-79,289 (-79%)

Excluding Drought Year Generations

$\text{Log } Y = 4.944499 - 0.052369x; \; r = -.80$

Year	Calculated Population		Decline per Generation Number	%
1967	78,006	x		
1968	69,145	one		
1969	61,290	Generation		
1970	54,327	x	23,679	30
1971	48,156		20,989	30
1972	42,686		18,604	30
1973	37,837		16,490	30
1974	33,538		14,618	30
1975	29,729		12,957	30
1976	26,351		11,486	30
1977	23,358		10,180	30
1978	20,705		9,024	30
1979	18,352		7,999	30
1980	16,267		7,091	30
1981	14,420		6,285	30
1982	12,782		5,570	30

Years	Ex	N	Mean Population
1967-69	208,440	3	69,480
1970-82	375,508	13	29,116
		Decline	-40,364 (-58%)

Table 10. This is a comparison between the 1967-69 average adult salmon count past Red Bluff and the 1970-78, 81 average count. It shows a total decline of 50,403 (60%) if the drought years (1979-80, 82) are excluded. If the drought years are included the decline is 57,850 (69%).

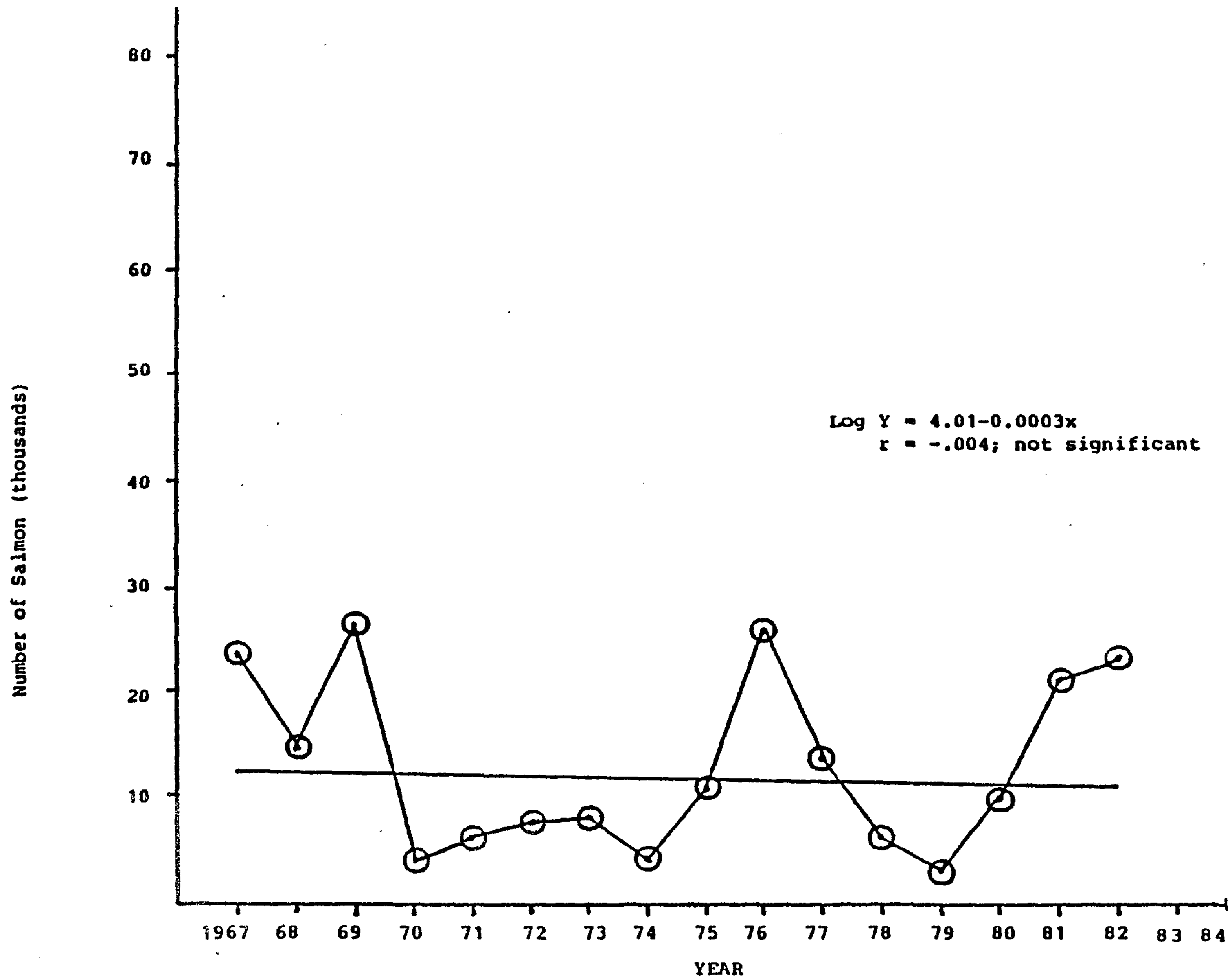

FIGURE 19. This is the calculated regression for numbers in Table 11. It shows a very slight decline between 1967 and 1982. This regression is not significant.

SPRING-RUN SALMON

Averages

Year	Ex	N	Mean Population
1967-68	37,902	2	18,925
1969-82	168,371	14	12,027
		Decline	-6,924 (-36%)

Regression

Log Y = 4.010173-0.000268x; r = -.004; not significant

Table 11. This is a comparison between the 1967-68 average adult salmon count past Red Bluff and the 1969-82 average count. It shows a total decline of 6,924 (36%).

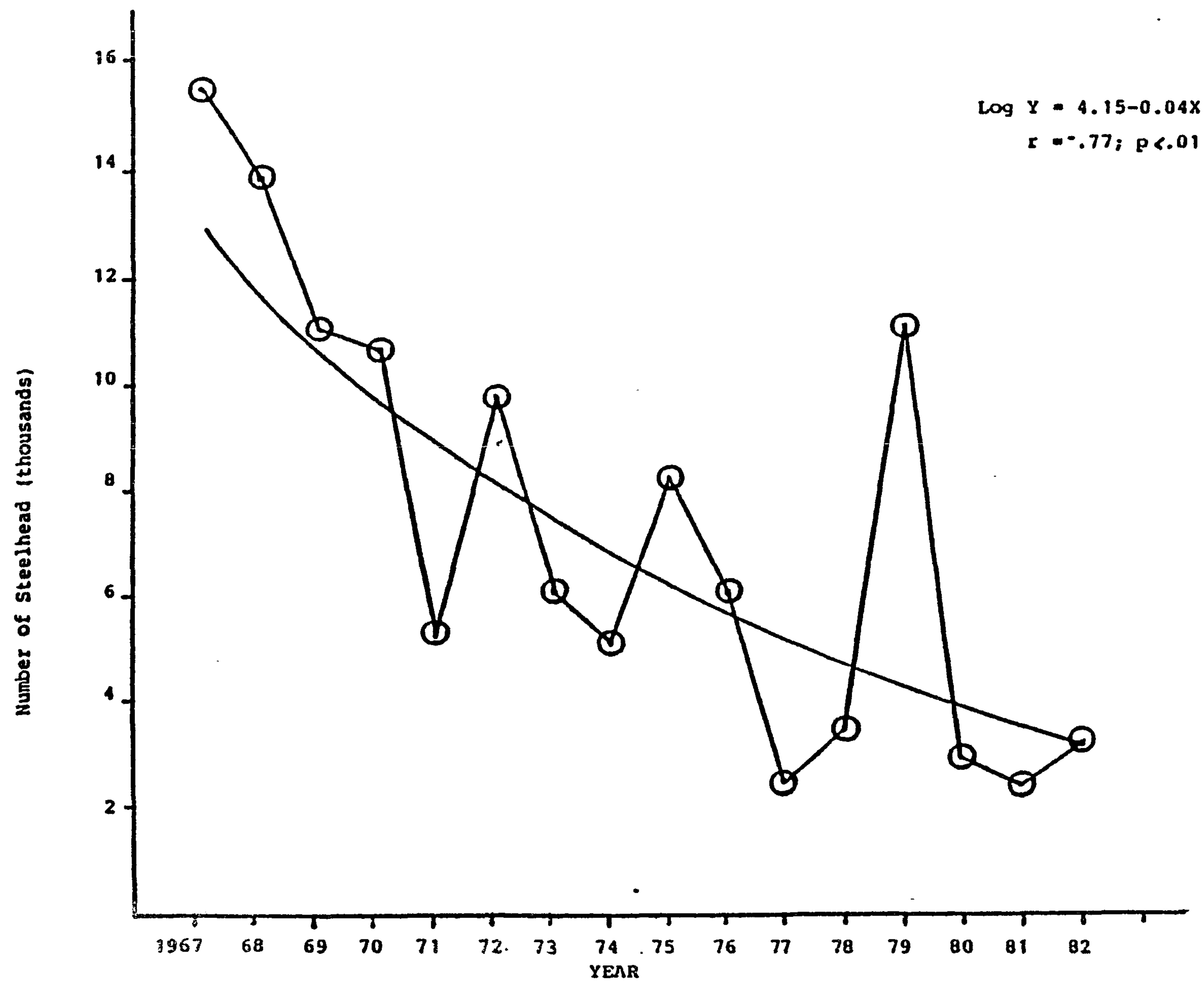

FIGURE 20. This is the calculated regression for numbers appearing in Table 12. The 1967-68 average steelhead count past Red Bluff is compared with the 1969-82 average. The difference between values of the regression line values indicates a total decline of 6,287 (51%), or 26% per generation. This regression is significant.

STEELHEAD

Averages

Year	Ex	N	Mean Population
1967-68	29151	2	14,576
1969-82	85197	14	6,686
		Decline	-8,490 (-58%)

Regression

Log Y = 4.151512-0.043569x; r = -.78

Year	Caculated Population		Decline per Generation Number	Percent
1967	12,822	one generation		
1968	11,589			
1969	10,491			
1970	9,489		3333	26
1971	8,583		3015	26
1972	7,764		2727	26
1973	7,023		2466	26
1974	6,353		2230	26
1975	5,746		2018	26
1976	5,197		1826	26
1977	4,701		1652	26
1978	4,252		1494	26
1979	3,846		1351	26
1980	3,480		1221	26
1981	3,148		1104	26
1982	2,847		999	26

Year	Ex	N	Mean Population
1967-68	24420	2	12,210
1969-82	82920	14	5,923
		Decline	-6,287 (-51%)

Table 12. This is a comparison between the 1967-68 average adult steelhead count past Red Bluff and the 1969-82 average count. It shows a total decline of 8,490 (58%).

Run	Year	Month	Number of Ripe Females Handled 1/	Estimated Total Eggs @ 5,000/♀♀
Late Fall -	1973	February	47	235,000
		March	242	1,210,000
		April 1-15	189	945,000
			478	2,390,000
Winter -	1975	May	195	975,000
		June	21	105,000
			216	1,080,000
Spring -	Average 1971-74	August 15-31	20	100,000
		September 1-30	17	85,000
			37	185,000
Fall -	Average 1971-74	October	176	880,000
		November	407	2,035,000
		December	79	395,000
			662 2/	3,310,000
	Estimated Annual Total		1,393	6,965,000

1/ Based upon females handled that were ready to spawn (actually losing eggs when handled).

2/ Does not include fish hauled to Tehama-Colusa Spawning Channel.

Table 13. Estimated number of king salmon eggs that could have been taken at Red Bluff Diversion Dam Fish Trapping Facility, during routine trap operation by the Dept. of Fish and Game.

give a boost to the endangered winter-run salmon, since over 1 million of the total eggs would come from ripe winter-run salmon in May and June.

Squawfish Predation

Between 1978 and 1985 the number of Sacramento Squawfish counted annually as they passed through the fishways at RBDD ranged from a low of 13,000 in 1983 to a high of 25,000 in 1978, and averaged about 18,000 (Figure 21). Squawfish concentrate below RBDD in the spring and early summer where they prey heavily on juvenile salmon on their way to the sea. Turbulence caused by water flowing under the dam gates disorients the juvenile salmon (which also pass under the dam gates) and increases their vulnerability to predation immediately below the dam. In June, 1977, squawfish sampled below the dam had consumed an average of 0.5 to 1.5 juvenile salmon shortly before capture. In May and June, 1977, an estimated 12,000 squawfish were concentrated below RBDD, that had a potential daily consumption rate in excess of 100,000 juvenile salmon. During the spring and summer months of some years (especially dry years) striped bass also become quite numerous and are serious predators of juvenile salmon immediately below RBDD. For example, in July, 1979, a 25-inch-long striped bass was captured below the dam, the stomach of which contained the remains of 21 juvenile salmon.

To control squawfish at RBDD an electronic shocking device was installed in the left bank fishway and tested in 1985. This device was quite successful in destroying adult squawfish in the fishway as they were migrating upstream. However, its operation had an adverse effect on salmon migration, so use of the shocker was discontinued. Apparently when squawfish, and some other species, are under stress a warning odor (pheromone) is emitted. In 1987 a new device is being tested in the left bank fishway which is aimed at reducing stress by capturing squawfish alive in the fishway, but destroying them elsewhere. Part of the money for this latter device was furnished by the Marin Rod and Gun Club.

Lake Red Bluff Power Project

The City of Redding has submitted an application for license to the Federal Energy Regulatory Commission (FERC) for the Lake Red Bluff Power Project (FERC No. 2827, April, 1983). FERC has denied the permit, but Redding has decided to appeal. The City of Redding's plan is somewhat similar to a plan developed by the Bureau of Reclamation to develop power at RBDD--a plan that the Bureau is not actively seeking approval to implement at this time.

A major concern with the City of Redding's proposed power project is the potential direct turbine mortality of juvenile salmon and steelhead migrating downstream; i.e., those fish which cannot be diverted or screened from passing throught the turbines. Indirect mortality, i.e., increased predation on stunned, disoriented or debilitated juveniles that have passed through the turbines could also be significant. Adult salmon and steelhead passage upstream at RBDD could also be adversely affected, since the proposed project provides for inadequate fish attraction flows to the fishways.

Recommendations

There are presently three action study programs involving the Bureau of Reclamation and FWS aimed at implementing solutions to the fishery problems at RBDD. These studies should be continued. Although considerable improvement in total numbers of salmon and steelhead, and their distribution above and

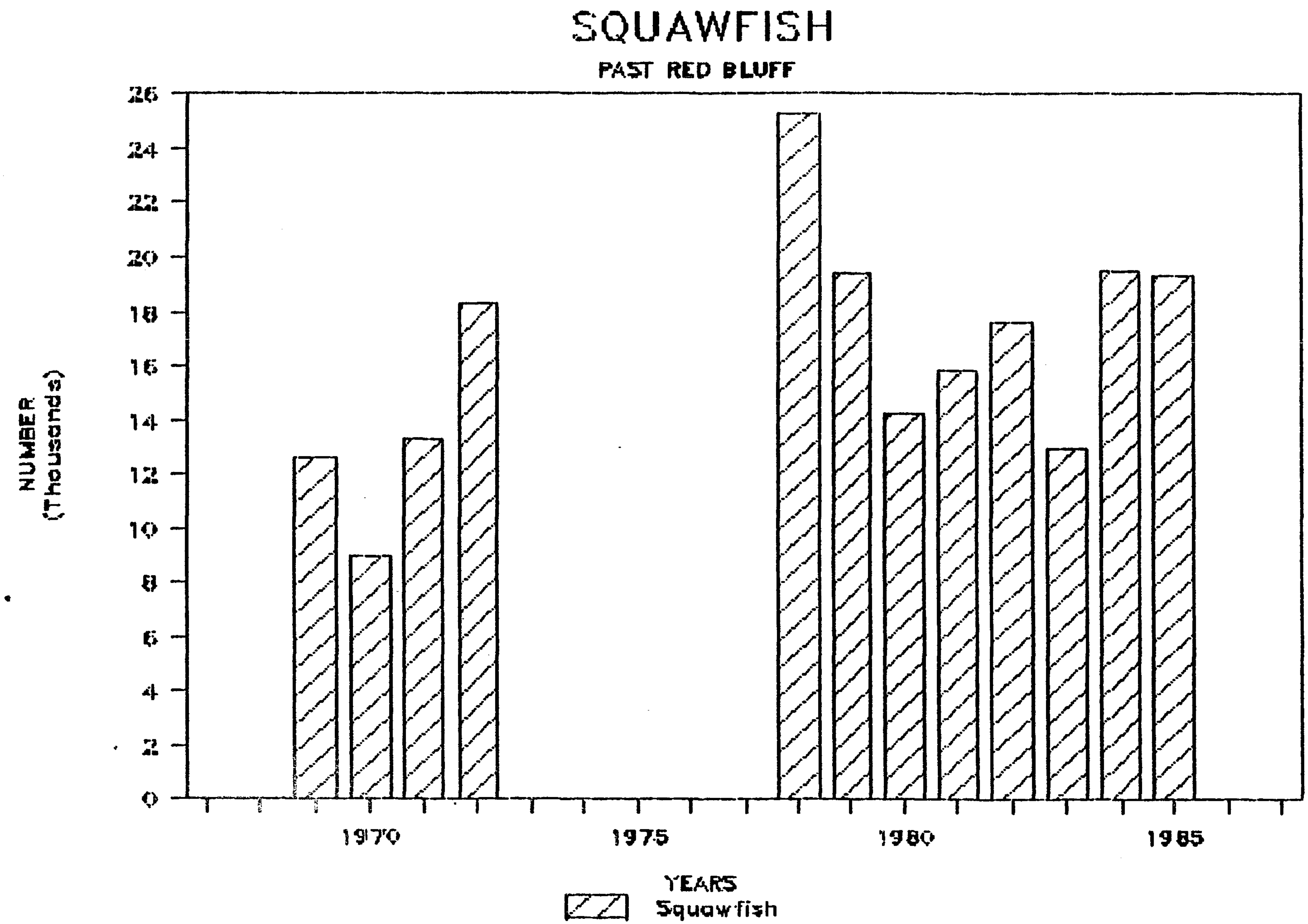

FIGURE 21. Numbers of Sacramento Squawfish counted at Red Bluff Diversion Dam.

below the dam should result from these studies and from predator control, it is doubtful that manipulation of RBDD operations, within the constraints of present and proposed future water demands, will ever completely reverse present losses. Strictly from a fisheries standpoint, the logical solution to RBDD fish passage problems would be to replace the dam with a pumping plant to supply water to the Tehama-Colusa and Corning Canals. At the Glenn-Colusa Irrigation District, a pumping plant similar in size to the one that would be required at Red Bluff, was installed at a cost of $10 million in 1984. If RBDD is not to be replaced with a pumping plant, or another source of water is not developed which would allow raising of the gates,a formal agreement should be made relative to raising the gates at least during the non irrigation season to improve fish passage.

Until studies demonstrate that ripe salmon handled at RBDD trapping facility spawn successfully in the river if released, they should be spawned artificially and their spawn placed in the FWS incubation station constructed for that purpose. Operation of this facility should be funded by the Bureau of Reclamaton, owners and operators of RBDD.

Studies should be continued to develop a positive plan for eliminating squawfish predation at RBDD.

The City of Redding's proposed Lake Red Bluff Power Project should be opposed unless all fish protective measures to be recommended by DFG and FWS are incorporated in the project.

Winter-Run Salmon

Description

Winter-run salmon are a true race, and by definition a subspecies of chinook salmon found only in the Sacramento River system (and from time to time in the Calaveras River). About 98% spawn in the main stem of the Sacramento River. Prior to construction of Shasta and Keswick Dams their principal spawning area was in the Sacramento River system upstream from Redding, and particularly in the McCloud River. They now spawn in the Sacramento River from below Keswick Dam at least to Tehama, but primarily upstream from Red Bluff. A few occasionally spawn in tributaries such as Mill and Battle Creeks.

Winter-run salmon have a life history somewhat different from the other races of Sacramento River salmon. In general they have a three-year life cycle, with the spawning adults consisting of more two and three-year-old fish than the other races, which have more three- and four-year-old fish. Winter-run salmon are also less susceptible to the ocean fisheries, since they leave the ocean primarily as three-year-old fish in the winter.

Most winter-run salmon are landed in the ocean between Monterey and Fort Bragg; 71% are caught by sport fishermen and 29% by commercial fishermen. Of those that return to spawn, about 10% are caught by sportsmen in freshwater. The catch to escapement ratio is 0.66-to-1, which represents a harvest rate of only 40% . The other salmon populations have a harvest rate which is closer to 65%. However, in spite of their low harvest rate, a spawning population of 117,000 winter-run salmon (1969) would have contributed over 77,000 fish annually to the ocean fisheries at a catch to escapement ratio of 0.66-to-1.

Decline

Populations of winter-run salmon have been declining at least since 1969. Counts of winter-run salmon passing RBDD from 1967 through 1984 range from a high of 117,000 in 1969 to a low of 1,156 in 1980. The average count for the three-year period 1982-84 is only 2,056. The calculated (from regression) populations or runs indicate an average decline of 51% per generation during the 1967-84 period (Figure 22 and Table 14).

Some factors contributing to the decline of winter-run salmon are:

1. Two year classes were lost due to drought conditions in 1976 and 1977 when river water temperatures were nearly 70 degrees Fahrenheit during the spawning periods. Low fecundity (3,353 eggs/female) also contributed to the difficulty of "bouncing back" after such a disaster.

2. At Red Bluff Diversion Dam there is a delay of 1 to 40 days (av. 18) among those winter-run salmon that pass the dam; and of those winter-run salmon that approach the dam, 37.5% fail to pass (Table 5). Delay time increases with flow past the dam; i.e., the greater the flow between 4,000 cfs and 16,000 cfs the longer the delay (Figure 15). Downstream from RBDD water temperatures were suitable for winter-run spawning and incubation (50 to 57 degrees F.) only 4 out of 18 years (22% of the time) between 1967 and 1984.

3. It is assumed that losses to some degree also occur among juvenile winter-run salmon passing RBDD in the fall, since losses also occur among juvenile salmon that pass the dam in the spring as well as in the winter.

4. DFG data indicate that during August, September and October, 25%, 16.4% and 7.2% respectively of the juvenile outmigrant winter-run salmon have been destroyed at the GCID pumping plant, in years when the fish screen there was ineffective.

Recommendations

If RBDD is to remain in operation, raise the gates full time from December 1 through March 31 (the non-irrigation season). A formal agreement to this effect should be made, and it should remain in effect until the population returns to suitable levels. The estimated effect of this action would be to improve the winter-run loss from about 50% per generation to only 30% per generation. If the freshwater sport catch was also eliminated, the decline would improve to a loss of only 20% per generation.

Flushing flows in the Sacramento River, similar to those now being made for fall-run salmon juveniles, should be made in the fall for winter-run outmigrants.

Restrict the sport fishery in the Sacramento River for winter-run salmon.

The winter-run salmon hatchery program at CNFH should be speeded up. A new hatchery, specifically for winter-run salmon should also be considered for the upper Sacramento River, as well as the establishment of a "gene pool" of winter-run salmon at Feather River Hatchery.

The status of the winter-run salmon qualifies it for listing as endangered or at least threatened. It should be listed, unless corrective measures for restoring the runs are guaranteed in writing. Habitat problems in the upper Sacramento River should be corrected, including mining pollution, gravel recruitment and water quality (temperature).

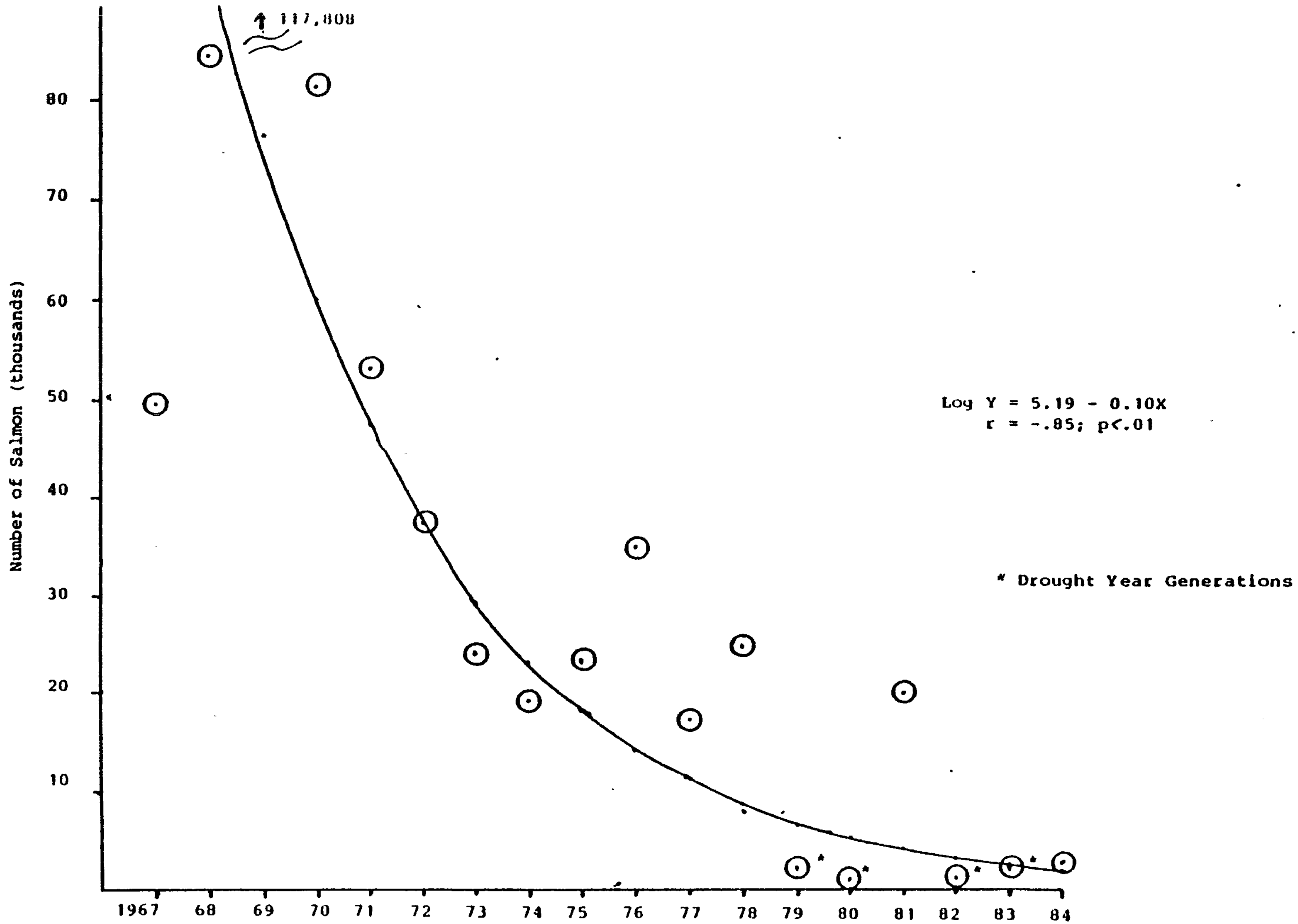

FIGURE 22. Numbers of adult winter-run chinook salmon counted passing Red Bluff Diversion Dam, 1967-84.

	Adjusted Counts 7/	Calculated Counts From Regression Log Y= 5.19--0.10x r= -.85 p= .01		
			Decline Per Generation	
Year	Number	Number	Number	Percent
1967	49,533 1/2/	123,169	One	
1968	84,414 2/3/	96,942	Generation	
1969	117,80 2/4/	76,300		
1970	81,159 2/5/	60,053	63,116	51
1971	53,089	47,265	49,677	51
1972	37,133	37,201	39,099	51
1973	24,079	29,279	30,774	51
1974	19,116	23,044	24,221	51
1975	23,430	18,137	19,064	51
1976	35,096	14,276	15,003	51
1977	17,214	11,236	11,808	51
1978	24,862	8,843	9,294	51
1979	2,364	6,960	7,316	51
1980	1,156	5,478	5,758	51
1981	20,041	4,311	4,532	51
1982	1,242	3,394	3,566	51
1983	2,262 6/	2,671	2,807	51
1984	2,663	2,102	2,209	51

1/ 8-hour counts, adjusted for 14-hour counting period (x1.75).
2/ Counts reconstructed by adjusting actual counts to their respective run each.
3/ Adjusted for missing counts (actual count 61,369).
4/ Adjusted for missing counts (actual count 80,934).
5/ Adjusted for missing counts (actual count 52,185).
6/ Adjusted for missing counts (actual count 405).
7/ Counts represent at least 95% of the total run.

Table 14. Winter-run salmon spawning runs past Red Bluff Diversion Dam showing decline per generation (3-years) based on regression, 1967-84 7/.

Tehama-Colusa Fish Facilities

Description

Red Bluff Diversion Dam impounds a lake about three miles long which inundates spawning riffles formerly used by about 3,000 salmon. To mitigate for this loss, and also to enhance salmon populations, the Tehama-Colusa Fish Facilities (TCFF) was constructed to produce a spawning population of 30,000 fall-run salmon. The value of the proposed enhancement number of salmon (27,000) of course made the entire water project much more feasible (Figure 23).

The upper 3.2 miles of the Tehama-Colusa Canal (TCC) is termed a Dual Purpose Canal because it provides a conveyance for irrigation water as well as a spawning area for salmon. There is a louver type fish screen at the headworks, near the right abutment. At the downstream end of the Dual Purpose Canal part of the water from the TCC is diverted into two single-purpose channels to be used exclusively for spawning and rearing salmon. The bulk of the water that is not diverted into the single purpose channels flows on down the TCC and is used primarily for irrigation. Water flowing through the single purpose channels discharges into Coyote Creek, and from there flows back into Sacramento River. The TCFF (1973-77 brood years) has produced an annual average of 4,575 adult salmon for the Sacramento River and 11,489 for the fisheries.

Dual Purpose Canal

To date the Dual Purpose Canal has been used only experimentally with small numbers of spawning salmon. The DFG in particular has been opposed to placing large numbers of spawners in it until it can be demonstrated that they would be at least as well off there as in the river. It was used only five years as a salmon spawning channel (between FY 1971-72 and FY 1980-81). During the 1975-76 through 1980-81 period, 728 females, and 781 males were placed in the channel, and 330,528 juveniles were counted as they migrated out, including juveniles that were entrained into the canal through the inefficient fish screen at the headworks (Table 15). Fish screen leakage is pointed out by the fact that in 1978-79 more than 61,000 juvenile salmon were counted out of the canal, even though no adults or juveniles had been placed in it. Had the 728 females been permitted to spawn in the river it is anticipated that they would have produced 910,000 juveniles, or three times more outmigrants than were counted out of the Dual Purpose Canal. Prespawning mortality among female salmon ranged from a low of 9% to a high of 94%, and averaged 46%. In the Sacramento River it averages 5%. Thus the Dual Purpose Canal has never come close to reaching its enhancement goal of 27,000 spawners, and it has considerable problems that need solving.

Single Purpose Channels

The single purpose spawning channels are doing an adequate job of providing a home for the 3,000 salmon that normally spawned in the area inundated by Lake Red Bluff. They have been in operation since 1971 (16 years), and an average of 3,146 adults have spawned there annually. The average egg deposition to juvenile outmigrant is 19.3% (Table 16). This is about equivalent to what would be expected to happen if the salmon had spawned in the Sacramento River. One problem is that posed by the drum type fish screen

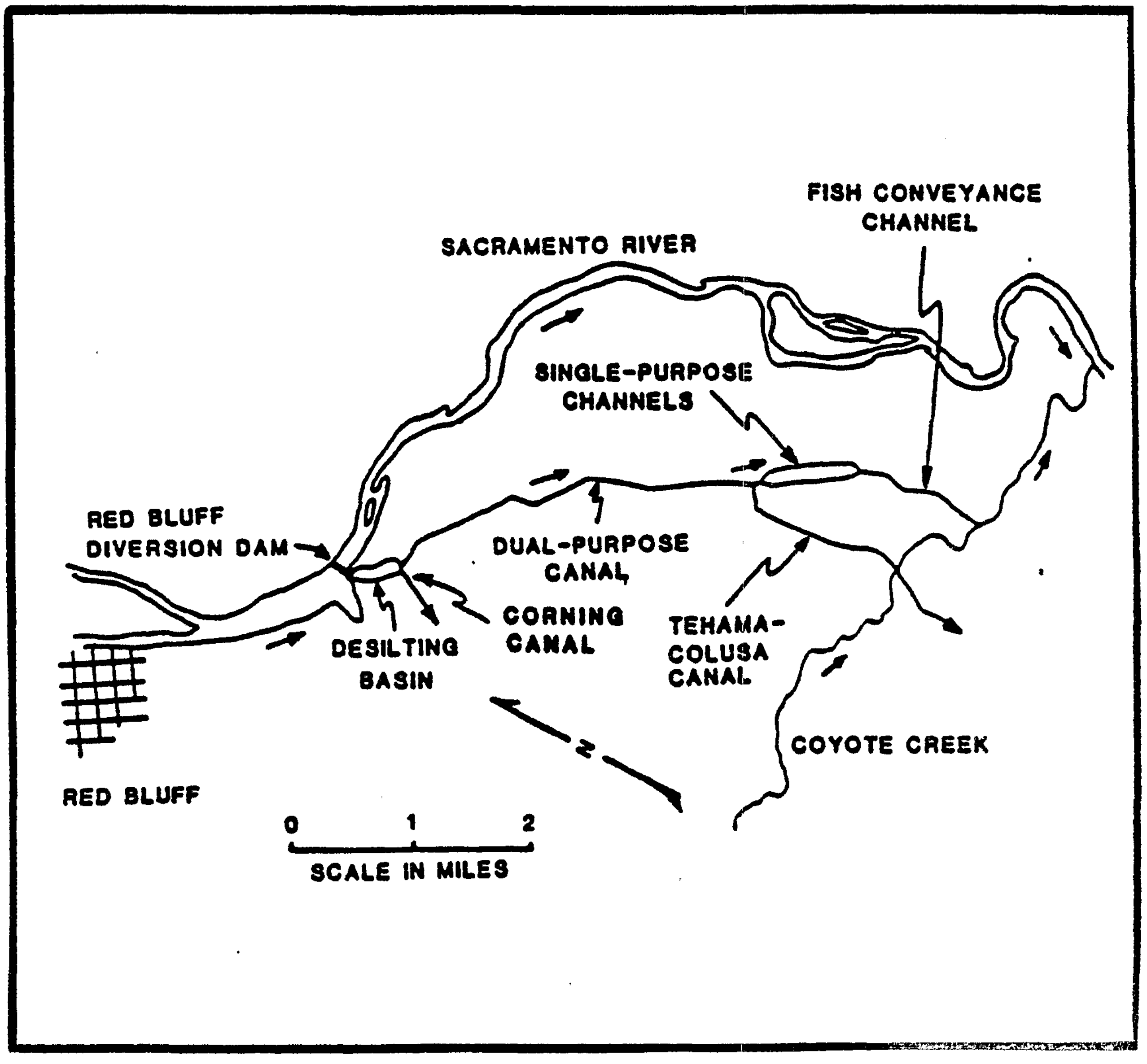

FIGURE 23. Location of the Tehama-Colusa and Corning Canals.

		Spawners					Eggs	Juveniles released			
Year[a]	Stocking period	Spawners stocked	Females stocked	Sex ratio (female/male)	Fecundity (eggs/female)	Female prespawning mortality[b]	Egg deposition	Juveniles released[c]	Percent survival	Mean size (fish/lb)	Total weight (lbs)
1971-72	Oct. 6 - Dec. 12	1,008	N.R.	45/55	7,053	120(34.4%)	1,500,000	226,200[d]	15.08[e]	N.R.	2,262[d]
1972-73	---------- Not utilized for fish production ----------										
1973-74	---------- Not utilized for spawning ----------						1,724,000[f] F	234,793[g]	N.R.	N.R.	N.R.
1974-75	---------- Not utilized for fish production ----------										
1975-76	Oct. 30 - Nov. 7	375	176	47/53	N.R.	N.R.	900,000[h]	135,036	N.R.	25	5,371
1976-77	---------- Not utilized for spawning ----------						179,695[i] F	38,741	22	26	1,502
1977-78	Nov. 3	854	420	49/51	N.R.	N.R.	N.R.	108,750[j]	N.R.	N.R.	2,226
1978-79	---------- Not utilized for spawning ----------						N.R.	61,487	N.R.	63	969
1979-80	N.R.	120	71	59/41	N.R.	67(94%)	N.R.	11,030	N.R.	36	303
1980-81	Oct. 15-31	160	61	38/62	N.R.	3(9.4%)	N.R.	75,712	N.R.	56	1,340

a Period from July 1 through June 30.
b Number of unspawned female carcasses recovered in the DPC. The percentage calculated is the percentage of the total female carcasses recovered which were unspawned. All spawners stocked are not subsequently recovered.
c Does not include fish leaked through drum screen at the terminal fish counting facility.
d Estimate based on assumption of identical survival and size of juveniles in DPC and in SPC.
e Assumed identical to SPC.
f Salmon fry only were planted from Feather River Hatchery, Coleman National Fish Hatchery, and TCCFF incubation station. The plants were made January 18 - March 7, 1974.
g Actual release unknown due to excessive drum screen leakage at the DPC. Juvenile production is reported as 234,793 in the production report, 1973-74 season--22,554 leaked into the SPC, 210,553 leaked into the TCC, and 1,686 were counted through the fish counter. Subsequent production reports cite the total as 211,000.
h Estimate based on assumption of identical fecundity (6,000 eggs/female) as in SPC and that 150 of the planted females spawned.
i Salmon fry only were planted from the SPC January 29 - March 26, 1977. The total weight of the fry was 217 pounds.
j Production was cited as 87,597 and 108,750 in the production report, 1977-78 season. Subsequent reports cite production as 108,750.
N.R. - No record.

Table 15. Chinook salmon production in the dual-purpose canal and spawning channel, Tehama-Colusa Canal Fish Facilities (data from Tehama-Colusa Fish Facilities production reports 1971-72 season through 1977-78 season and fiscal year 1979 through fiscal year 1981).

Year[a]	Stocking period	Spawners stocked	Females stocked	Sex ratio (female/male)	Fecundity (eggs/female)[b]	Female mean length (in.)[b]	Female reeapawning mortality[c]	Egg deposition	Juveniles released[d]	Percent survival	Mean size (No./lbs)	Mean length at release (in.)	Total weight released (lbs)
1971-72	Oct.5-Nov.7	4,028	1,930	48/52[e]	6,995	31.8	714 (39.6%)	7,248,000	1,094,000	15.1	215[e]	2.5	5,097
1972-73	Oct.25-Dec.1	1,781	914	51/49[e]	6,410	31.1	130 (14.4%)	4,793,000	1,088,000	22.7[e]	255	2.3	4,288
1973-74	Oct.9-Nov.11	3,377	1,415	42/58	5,344	28.0	87 (6.5%)	6,571,000	418,000	6.4[e]	224	2.4	1,871
1974-75	Oct.15-Nov.22	3,077	1,409	46/54[e]	6,140	28.7	127 (9.4%)	7,418,000	4,448,000	60.0	815	1.6	5,461
1975-76	Sep.29-Nov.30	3,592	1,571	44/56[e]	6,083	29.2	123 (8.0%)	8,474,000	1,122,000	13.2	237	2.4	4,731
1976-77	Oct.18-Nov.22	3,312	1,525	46/54[e]	5,440	27.5	229 (15.8%)	6,585,000	734,000[e]	11.2	339[e]	2.1	2,167
1977-78	Oct.27-Nov.19	3,957	1,887	48/52[e]	6,003	29.0	158 (9.4%)	9,149,000	1,309,000	14.3	423[e]	2.1	3,097
1978-79	Oct.3-Nov.6	4,137	1,906	46/54[e]	5,712	28.2	262 (13.7%)	9,402,000	469,000	5.0	216	2.5	2,174
1979-80	Oct.3-Dec.8	2,508	1,007	40/60[e]	5,928	28.8	88 (9.0%)	5,288,000	1,016,000	19.2	599	1.8	1,694
1980-81	Oct.9-Nov.23	1,689	720	42/58[e]	4,740	26.9	20 (2.8%)	3,285,000[e]	841,000	25.6	684	2.1	2,242
Mean	--	3,146	1,428	45/55[e]	--	--	194 (12.9%)	6,821,000[e]	1,254,000[e]	19.3[e]	--	--	3,282

[a] Period from July 1 through June 30.
[b] Data from FWS, 1972-81.
[c] Number of unspawned female carcasses recovered in the SPC. The percentage calculated is the percentage of the total female carcasses recovered which were unspawned. All spawners stocked are not subsequently recovered.
[d] Does not include fish leaked through drum screens at the terminal fish-counting facility.
[e] Corrected data from Vogel, personal communication.

Table 16. Chinook salmon production in the single-purpose spawning channels, Tehama-Colusa Canal Fish Facilities (Data from Tehama-Colusa Fish Facilities production reports 1971-72 season through 1977-78 season and fiscal year 1979 through fiscal year 1981).

D-019913

at the terminal fish counting facility. Estimated minimum counts indicate that from 2.1% to 64.9% of the annual salmon production escapes into Coyote Creek prior to rearing (fish screen leakage), depending primarily upon turbidity.

Rearing Facility

To operate the single purpose channels as spawning channels it would be necessary to keep RBDD gates down most of the year, or an alternate source of water would be required when the gates were up. If fall-run salmon were permitted to spawn in the single purpose channels, and the gates were up during the non-irrigation season (December 1 - March 31), another source of about 30 cfs of water would be required during that period for egg incubation and juvenile rearing. However, salmon and steelhead losses in the Sacramento River, caused by RBDD operation, far outweigh present spawning channel production at TCFF.

Production, in terms of catch and escapement, can be increased considerably even if RBDD gates are raised during the non-irrigation season, by converting the single purpose channels into a rearing facility. This has already been accomplished experimentally on a modest scale in the lower 1,000 feet of the single purpose channels. The lower 1,000 feet has also been covered with anti-predation netting to eliminate avian predation on juveniles. Surplus 90/lb juvenile salmon from CNFH have been transferred to the single purpose channels rearing area during each of the past three years, resulting in the production of an estimated 400,000 outmigrants in 1985 and 310,000 in 1986, averaging 5/lb (1987 production has not been released). Although marked fish from these groups have not been recovered in quantities sufficient to permit an evaluation, based upon the size at release, rearing salmon to the larger size (from 90/lb to 5/lb) should increase adult returns to the fisheries and spawning stocks by 8 to 10 times (Figure 24).

Recommendations

The TCFF should not be operated as a spawning channel facility if it is necessary to keep RBDD gates down in order to do so. Instead, the Dual Purpose Canal should be abandoned, and the single purpose channels converted to rearing facilities which can operate with RBDD gates up during the non-irrigation season.

If present studies show increased production from converting part of the single purpose channels to a rearing facility, the rearing facility should be expanded to a production capacity of 2 million sub-yearlings at 5/lb.

Replacement of the louver fish screen at the headworks with a positive screen should be speeded up (by the Bureau of Reclamation).

If RBDD gates are to be raised during the non-irrigation season, the Dual Purpose should be abandoned as a fish facility. Otherwise, studies should be continued to find out if any production there can be salvaged.

Unscreened Diversions and GCID Fish Screen

Background

Studies by both DFG and FWS have demonstrated that in general juvenile salmonids migrate seaward in proportion to stream flow, i.e., if 10% of the flow enters a diversion or goes down a particular river channel, 10%

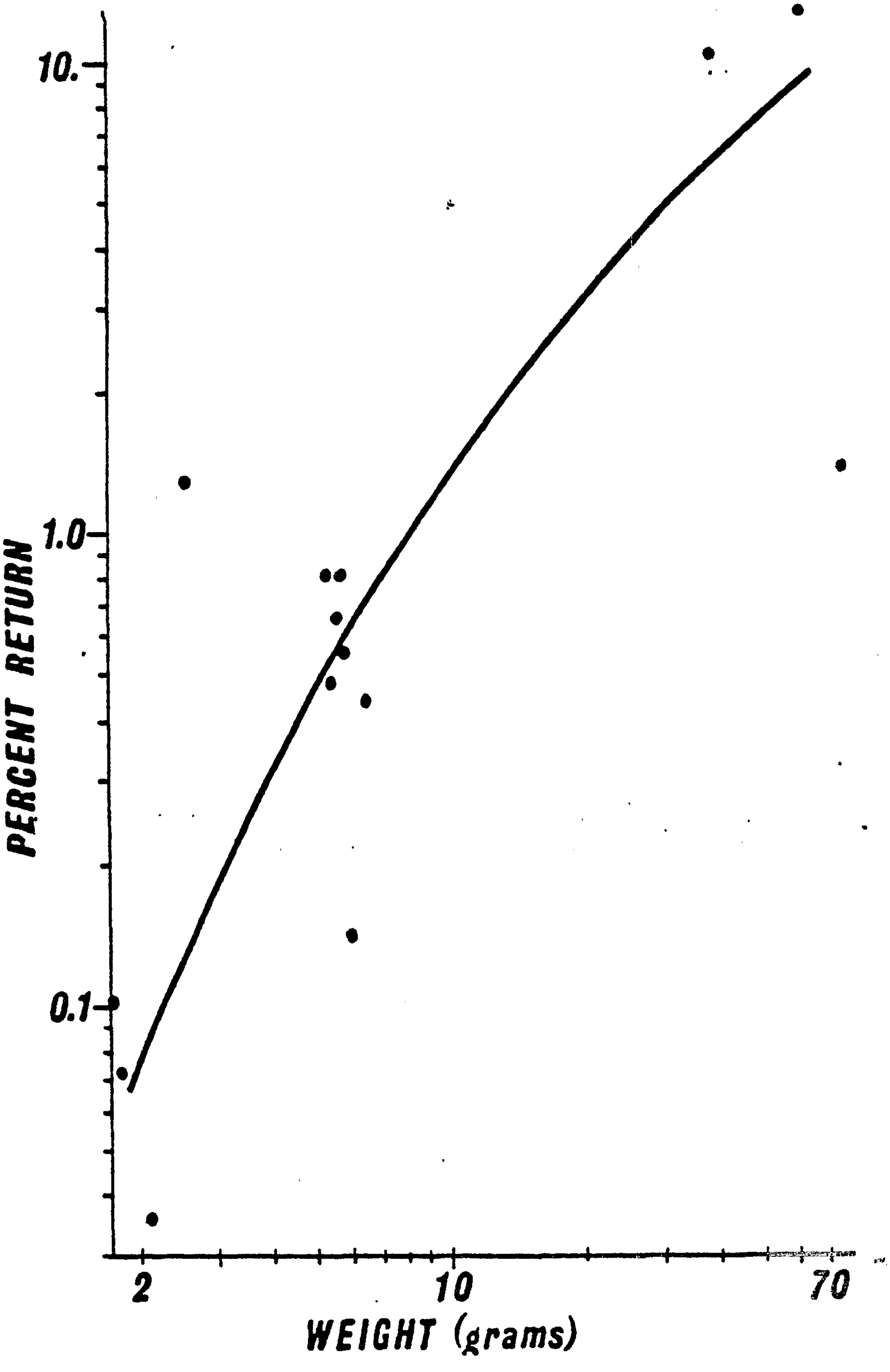

FIGURE 24. Percent recovery by the ocean fisheries and at the hatchery of marked groups of fall-run chinook salmon released in the Sacramento River system at different sizes (curve fitted by inspection).

of the juveniles migrating at that time will also go that way. Thus in most instances the larger a diversion is, the greater juvenile losses are likely to be in that diversion, provided it is not screened properly. In addition to juvenile losses in unscreened diversions, the studies have also shown that where there is no trash grid or rack at the headworks of a diversion the losses of adult salmon can be considerable.

There are more than 300 separate irrigation, industrial and municipal water supply diversions along the Sacramento River between Redding and Sacramento. Most of these diversions are for irrigation, and consist of single and double pump installations supplying water to limited acreages. However, at Red Bluff and particularly between Butte City and Knights Landing there are several huge irrigation diversions. Of the total diversions, only two divert by gravity; the remainder divert water by pumping. There are also more than 30 diversions from Sacramento River tributaries in areas utilized by salmon and steelhead.

Of the total diversions along the Sacramento River, only three have fish screens: (1) Anderson-Cottonwood Irrigation District, (2) Tehama-Colusa Canal and (3) Glenn-Colusa Irrigation District. The Anderson-Cottonwood fish screen works satisfactorily, the Tehama-Colusa Canal screen is very inefficient and scheduled for replacement by the Bureau of Reclamation, and the Glenn-Colusa Irrigation District screen does not work at all. There are 13 fish screns on tributary stream diversions, in areas used by anadromous fish, all of which work satisfactorily (Figures 25, 26 and Table 17).

Amounts of Water Diverted

Nearly 1,200,000 acre feet (AF) of water is now diverted annually from April through October into unscreened diversions along the Sacramento River between Redding and Sacramento. Between Redding and Red Bluff (River Mile (RM) 241-192) the unscreened diversions take only about 4,000 AF, and between Red Bluff and Ord Ferry (RM 191.0-141.5) only about 19,000 AF per year. However, between Red Bluff and Ord Ferry one diversion (M&T at RM 141.5) accounts for 18,000 AF, or 94% of the total diversions in this area. The bulk of the unscreened diversions occur between Ord Ferry and Knight's Landing (RM 141-34.5) where a total of almost 660,000 AF is diverted annually. In this river reach about 509,000 AF, or 77% of the total, is utilized by eight large diverters, including Reclamation District No. 108 (RM 43.10). An additional 493,000 AF is diverted into unscreened diversions between Knight's Landing and Sacramento.

Since the inefficient louver fish screen at the headworks of the Tehama-Colusa Canal is already scheduled for replacement by 1988, two of the greatest remaining juvenile salmonid loss problems along the Sacramento River include the GCID diversion and 10 or 15 of the larger unscreened diversions along the lower river.

Glenn-Colusa Irrigation District

The Glenn-Colusa Irrigation District (GCID) diversion, located on the Sacramento River four miles north of Hamilton City, is one of the largest irrigation diversions on the Sacramento River. It diverts an annual average of 767,000 AF of water from the Sacramento River. The GCID pumping plant was rebuilt in 1984 at a cost of $10 million, and has a capacity of 3,000 cfs.

The intake to the GCID irrigation canal is located on a side channel

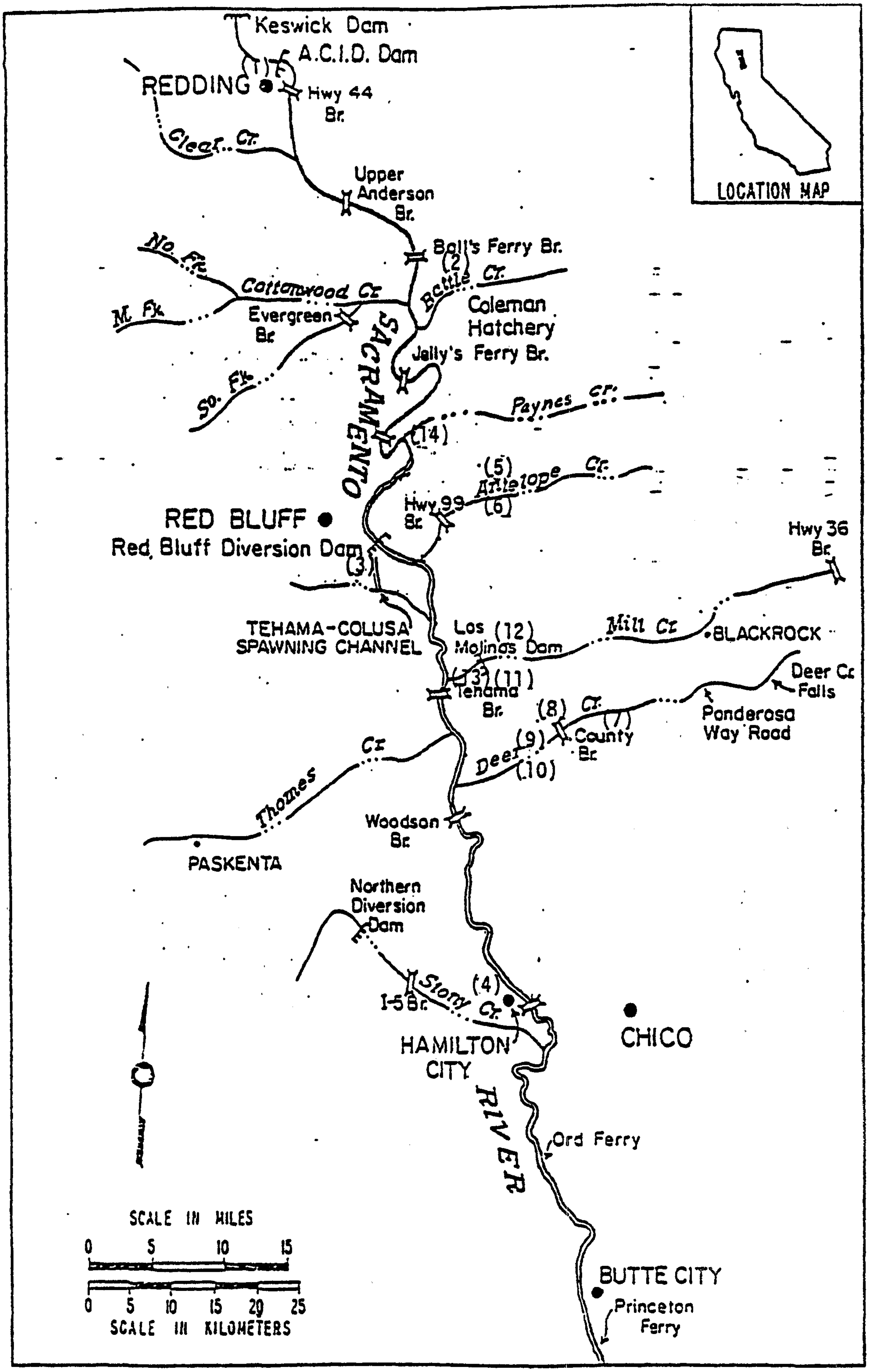

FIGURE 25. Location of fish screens in the Sacramento River System

D-019917

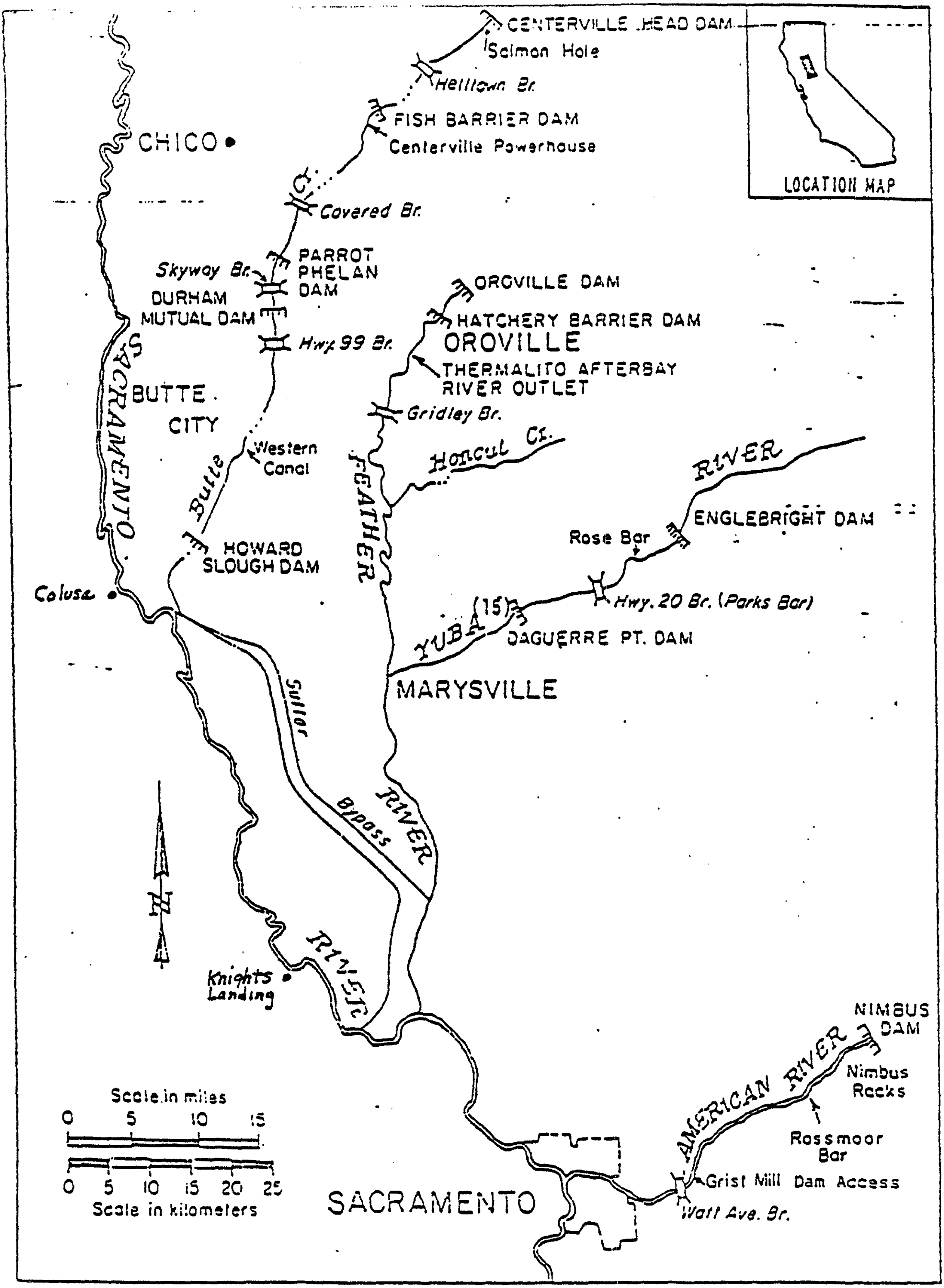

FIGURE 26. Location of fish screens in the Sacramento River system.

D-019918

1/	Fish Screen	Water	County	Installation Date	Period of Operation	Screen Type 2/	Diversion (CFS)	Bypass (CFS) 3/	Velocity Approach (FT/S)
(1)	Anderson Cottonwood Irrigation District	Sacramento R.	Shasta	1969	Apr-Oct	VI	400	11	.3
(2)	Gover	Battle Cr.	Shasta	1965	Apr-Oct	VI	100	3	.3
(3)	Tehama Colusa	Sacramento R.	Glenn	1966	All Year	VIII	700-2400	120	.3-.9
(4)	Glenn Colusa	Sacramento R.	Glenn	1972	Mar-Nov	III	1800-2700	90	.4-.6
(5)	Edwards	Antelope Cr.	Tehama	1977	Apr-Oct	VII	50	0	.2
(6)	Los Molinos Water Co.	Antelope Cr.	Tehama	1978	Apr-Oct	VII	70	0	.2
(7)	Canyon Mouth	Deer Cr.	Tehama	1975	Apr-Oct	VI	45	1	.2
(8)	Kimball	Deer Cr.	Tehama	1980	Apr-Nov	VII	10	0-5	.3
(9)	North Stanford Vina	Deer Cr.	Tehama	1974	Apr-Oct	VI	45	0	.2
(10)	South Stanford Vina	Deer Cr.	Tehama	1971	Apr-Oct	VI	100	0	.3
(11)	Clough	Mill Cr.	Tehama	1955	Apr-Oct	VI	20	1	.3
(12)	Upper Mill Creek	Mill Cr.	Tehama	1972	Apr-Oct	VI	100	0	.3
(13)	Lower Mill Creek	Mill Cr.	Tehama	1958	Apr-Oct	VI	70	0	.3
(14)	Paynes Creek	Paynes Cr.	Tehama	1980	Apr-Oct	VII	10	0-5	.21
(15)	Hallwood Cordua	Yuba R.	Yuba	1973	Mar-June	VI	300-600	1	.1-.3

1/ Number corresponds to location shown on Plate 1.
2/ Screentype as numbered in Appendix A.
3/ Two numbers indicate normal and maximum bypass flow.

Table 17. Fish screens in the Sacramento River System.

of the river, or oxbow, leading off the right bank (Figure 27). The side channel is maintained by GCID. During the irrigation season, an earthen dam is usually placed across the side channel immediately downstream from the irrigation canal intake to provide a better head for the pumping plant.

The GCID fish screen, situated at the intake to the irrigation canal just upstream from the pumping plant, is considered to be one of the world's largest fish screens. It is a rotating drum type fish screen, designed and constructed to prevent juvenile salmonids, in particular, from entering the irrigation canal at water diversions of up to 3,000 cfs. It consists of 40 drums, each 17 feet high and 8 feet wide. The fish screen design originally required a 90 cfs bypass flow in the side channel downstream from the screen, and earthen dam, to lead "screened" fish back to the Sacramento River (Figure 27). Funds totaling $2.6 million were spent by the DFG in 1972 to construct the GCID fish screen. It is estimated that such a screen would now cost close to $10 million.

The Problem

Since 1980, the Sacramento River near the entrance to the side channel has been significantly altered. Channel degradation has lowered the river bed elevation by nearly two feet, causing sedimentation in the intake channel, and limiting the ability of GCID to divert the desired amount of water for irrigation. Operation of the pumping plant now results in flow reversals in that portion of the intake channel downstream from the fish screen. Instead of a downstream flow of water from the fish screen bypasses to the Sacramento River, the flow from both the upstream and downstream ends of the intake channel is towards the fish screen and pumps. Fish approaching the irrigation canal intake are thus trapped in front of the fish screen during these periods of flow reversal, resulting in a total loss. Because of the decrease in elevation, the drum type fish screens no longer have enough water covering them to function properly. Under present conditions the original agreed upon bypass flow of 90 cfs is inadequate to assure that if fish are bypassed by the fish screen they will be guided back to the river. A bypass flow of at least 500 cfs and probably close to 1,000 cfs would now be necessary to satisfactorily return "screened" fish to the river. In effect, if GCID were diverting between 1,000 and 3,000 cfs, the Sacramento River at the side channel entrance would have to flow between 10,000 and 16,000 cfs in order to assure a fish screen bypass of even 500 cfs; the greater the amount diverted, the greater the riverflow requirement.

Fish Losses

With the fish screens not working efficiently, losses of juvenile salmonids at GCID vary with the number of outmigrants passing the intake channel and the percent of water in the river that is being diverted into the channel. In most years an average of about 20% of the entire flow of the Sacramento River near Hamilton City is diverted into the irrigation canal between April and October (Table 18). This means that approximately 20% of the total juvenile salmonids moving downstream at that time are subjected to the fish screen. Even with the small size of recent salmon and steelhead populations, this juvenile loss could approach 7 million fish or more, and a loss to the ocean sport and commercial fisheries of 70,000 fish (Table 19).

Emergency Measures

Two emergency measures were initiated in the spring of 1985 to decrease fish losses at GCID: (1) installation and operation of an experimental trap

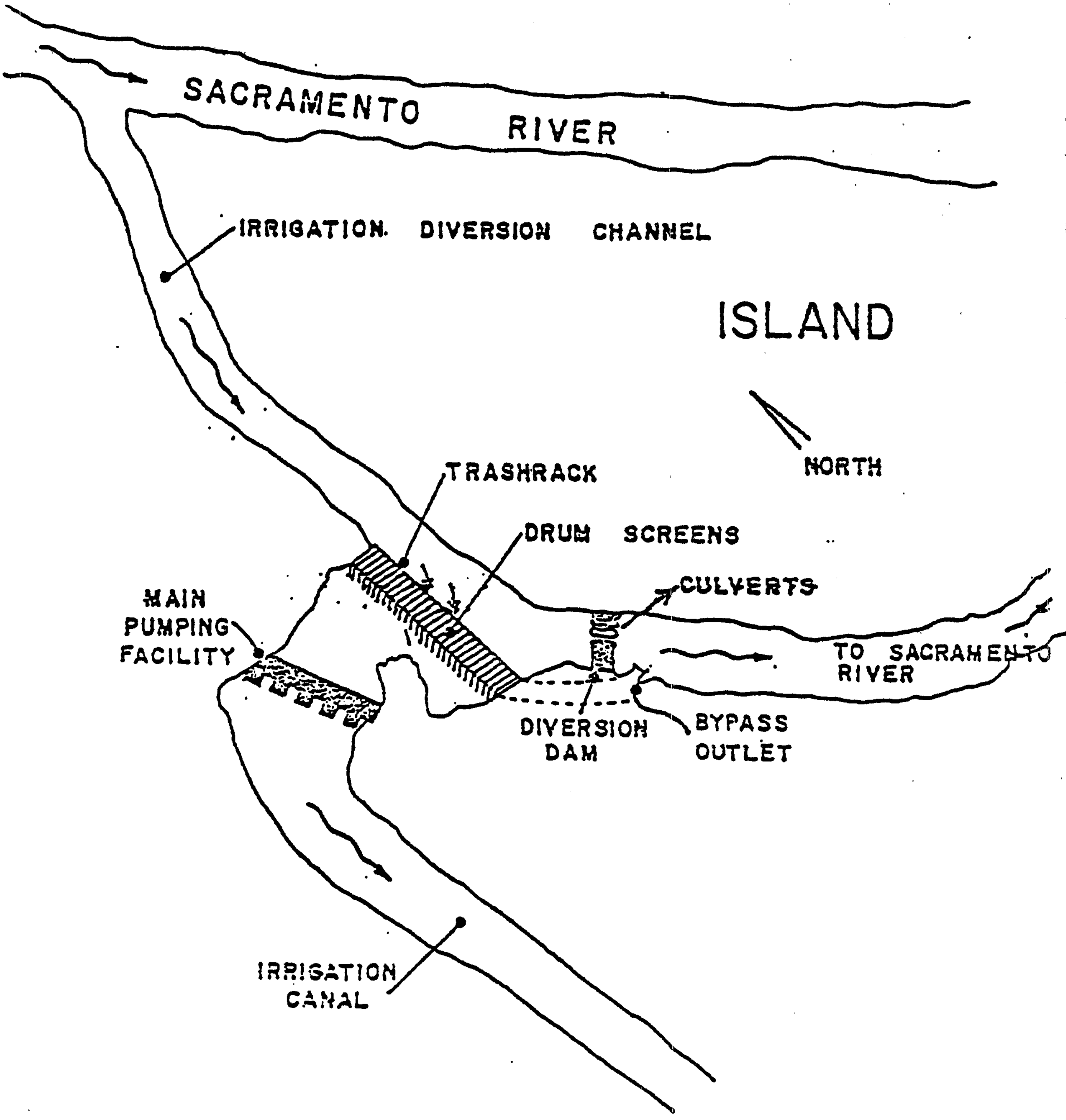

FIGURE 27. Diagram (not to scale) of the Glenn-Colusa Irrigation District diversion facilities.

Hamilton City Mean Monthly Flow (cfs)

Year	April	May	June	July	August	September	October
1979	8,821	8,420	7,986	10,742	7,022	4,848	5,581
80	8,503	6,845	9,174	8,514	5,762	5,862	5,121
81	9,647	9,054	8,409	10,176	9,916	5,451	4,606
82	35,220	15,180	9,172	8,148	8,387	8,538	8,545
83	27,193	24,967	17,567	13,103	11,932	9,667	10,175
				GCID Diversions			
1979	1,580	2,725	2,857	2,868	2,661	1,055	448
80	1,850	2,600	2,383	2,817	2,650	2,067	533
81	1,295	3,102	3,033	3,118	3,152	1,457	428
82	190	3,238	2,557	2,805	2,858	1,408	475
83	300	1,733	2,033	2,402	2,375	1,420	618
				Percent Diverted			
1979	15	22	26	21	27	18	7
80	18	22	21	25	32	16	9
81	12 Dry	26	27	23	24	21	9
82	0.5	18	22	26	25	14	5
83	1 Wet	6	10	15	17	13	6
Average	9.3	18.8	21.2	22	25	16.4	7.2

Table 18. River flow at Hamilton City, Glenn-Colusa Diversion flow, and calculated percent diverted, 1979-1983.

	Fall Coleman	Fall T-CFF	Fall Natural	Winter Natural	Spring Natural	Late-Fall Coleman	Late-Fall Natural	Steelhead Natural	Total
Month									
April		0.1	6.0		0.6		0.1	0.3	7.1
May	11.8	0.3	5.0		0.5		0.3	0.1	18.0
June			0.6		0.2		0.7	0.05	1.55
July			0.3				0.2		0.5
August				0.05			0.5		0.55
September				1.0	0.06		1.5		2.56
October				1.0	0.2	1.8	1.5	0.2	4.7
									34.96

Table 19. Estimated average number of juvenile salmonids exposed to Glenn-Colusa Diversion between April and October; 1979-83 (in millions).

D-019923

(at a cost of $40,000 to DFG) in one of the drum screen bays to collect and remove fish from the screen area, and (2) a coordinated program whereby CNFH production is released simultaneously with increased Sacramento River releases from Keswick Dam, and decreased GCID pumping (some water is wheeled to GCID from the TCC and Black Butte Reservoir on Stony Creek). The fish trap did not prove to be successful, but the coordinated increased flow- fish release program did; fish released in the upper Sacramento River during the elevated flow period reached the mouth of the Sacramento within eight days after release, and survived at a relatively high rate. This latter program was repeated in 1986 and 1987.

Recommendations

Although some diversion loss studies have been conducted in the past, an evaluation of fish losses at the 10 or 15 largest unscreened diversions along the Sacramento River should be made now, and a priority list for those needing screens developed, including type of screen needed and cost estimates. Such diversions for study should include, but not be limited to, the Sutter Mutual Water Company's Tisdale Plants No. 1 and No. 2, Reclamation District NO. 104, Provident Irrigation District, Reclamation District No. 108, and M&T Irrigation District.

A simple, uncomplicated principle should guide all approaches to fisheries restoration: You break it, you fix it. Until fish screening problems on the Sacramento are corrected, legislation should be considered which would require owners of unscreened diversions to make mitigation payments to DFG for fish destroyed. Losses would be based on the percent of the river flow diverted multiplied by the number of salmonids migrating downstream during the diversion period. Diverters should fund the studies necessary to determine numbers of fish migrating downstream.

The DFG should formulate a statewide fish screen policy. Whereas Region 1 has constructed and is maintaining a number of fish screens on anadromous fish streams in the upper Sacramento River system, as well as in the Klamath and Trinity River systems, Region 2 has very few of its diversions screened, and has actually abandoned some fish screens.

The coordinated increased river flow-fish release program initiated in 1985 should be continued.

Efforts to find a solution to the GCID fish screen problem, and problems at other large unscreened diversions from the Sacramento River, should be increased. The issue of responsibility for correcting the fishery loss problems at GCID and at other unscreened diversions should be determined. The California Sportfishing Protective Alliance and the United Anglers of California have asked (filed a complaint) the State Water Resources Control Board to determine whether or not GCID may be (1) making unauthorized diversions under a pre-1914 appropriative water rights, and (2) whether GCID's existing diversions from the Sacramento River are unreasonable under Section 275 of the California Water Code, because these diverions produce adverse impacts on the fisheries. This complaint could result in a thorough investigation by the Division of Water Rights and an eventual determination of responsibility at GCID, and perhaps at other unscreened diversions.

The DFG should take a firmer stance in dealing with GCID since their diversion, as it now exists, appears to be in violation of the Public Trust Doctrine as well as in violation of several sections of the DFG Code, which if enforced could eliminate much of the adverse effects of GCID operations.

The U.S. Army Corps of Engineers should limit GCID's dredge and fill permit to one year at a time, conditioned upon GCID installing and maintaining facilities which will reduce fish losses to a negligible level. In the meantime, GCID should be required to improve the present fish trapping facility, or to find a better method to temporarily reduce fish losses.

Clear Creek

Description

Clear Creek is a tributary that enters the Sacramento River from the west, a short distance below Redding. There are two dams on Clear Creek: Saeltzer Dam and Whiskeytown Dam. The 15-foot-high Saeltzer Dam, a privately owned diversion dam constructed in 1903, is located 6.5 miles from the mouth. The combination of an ineffective fish ladder, and the dam, effectively block anadromous fish from about 10 miles of the creek between Saeltzer and Whiskeytown Dams. Whiskeytown Dam, located 16.5 miles above the mouth was completed in 1963 by the Bureau of Reclamation, and now controls most of the flow in Clear Creek.

Both fall- and late fall-run salmon spawn in Clear Creek. Fall-run salmon spawning estimates range from a low of 330 in 1957 to a high of 10,000 in 1963 (Table 20). A total of 785 late fall salmon also spawned in Clear Creek during 1982. No estimates of the numbers of steelhead that spawn in Clear Creek are available, but local landowners have reported significant numbers in the creek, and attest to catching limits when steelhead fishing was permitted (Central Valley Fish and Wildlife Management Study, 1986).

The anadromous fish habitat in Clear Creek, especially downstream from Saeltzer Dam, has deteriorated primarily due to reduced stream flow, gravel mining, sediment deposition, riparian vegetation encroachment and water quality. Water releases into Clear Creek from Whiskeytown Dam now average 42,000 acre feet annually, which is less than 20% of the historical average flow at Whiskeytown. With tributary inflow, the flow in Clear Creek at Saeltzer Dam now averages 80,000 acre feet annually, or 30% of historic levels (Central Valley Fish and Wildlife Management Study, 1986).

Plans to Restore Fishery

Clear Creek, with low sustained summer flows below Whiskeytown Dam, is at present the only west side Sacramento River tributary that has a real potential for producing many steelhead, the young of which remain a year or more in freshwater prior to migrating to the sea. It also has a good potential for producing more salmon than it does now.

Three alternative plans to restore and enhance salmon and steelhead populations in Clear Creek have been evaluated recently by FWS to determine improvements in numbers of fish produced as well as cost effectiveness (CVFW Mgt. Study, 1986):

Alternative 1: Increasing the releases from Whiskeytown Dam by an average 85,700 acre feet annually would increase salmon spawners by 755 and steelhead spawners by 265. This plan would cost $7 million annually, primarily due to carrying high costs in terms of reducing CVP firm water yield and power output.

Alternative 2: Improving the habitat alone would increase salmon spawners by 6,040 and steelhead spawners by 590. The annual cost would be $370,000.

Alternative 3: Increasing the releases from Whiskeytown Dam by an average of 85,700 acre feet annually plus habitat improvement (combination

Year	Survey Trips	Actual Number of Carcasses Counted	Precent Recovery	Estimate
1951	Estimate based on single aerial survey redd counts			700 1/
1952	Estimatt based on single aerial survey redd counts			500 1/
1953	Estimate based on single aerial survey redd counts			1,580 1/
1954	No recorded information			
1955	-	-	-	1,003 2/
1956	4	530	20	2,650
1957	6	66	20	330
1958	6	313	20	1,600
1959	4	62	8	755
1960	6	116	13	900
1961	No survey	-	-	-
1962	2	1,071	20	5,400
1963	6	1,169	12	10,000
1964	3	718	29	2,500
1965	2	843	34	2,500
1966	5	230	26	900
1967	3	66	18	370
1968	5	280	35	800
1969	3	310	25	1;240
1970-75	No survey	-	-	-
1976	9	152	15	1,013
1977	5	165	12	1,362
1978	2	3	No estimate	
1979	2	76	No estimate	
1980	No survey			
1981	23	701	17	4,008 3/
1982	11	492	63	785

1/ Conducted by U.S. Fish and Wildlife Service (Warner, 1956).
2/ This figure represents an actual count of adult fish planted in Clear Creek that were trapped and trucked from the Keswick trap (Warner, 1956).
3/ Includes late fall-run estimate of 875.

Table 20. Fall-run chinook salmon spawning stock estimates for Clear Creek below Saeltzer Dam.

of 1 and 2) would increase salmon spawners by 13,320 and steelhead spawners by 13,285. The annual cost would be $7.5 million, primarily because of the high cost of the additional water released from Whiskeytown Dam.

Recommendations

Alternative No. 1 is the least effective both in numbers of fish produced and cost effectiveness. Alternative No. 2 is the most cost effective, but Alternative No. 3 produces the the most spawners. Improving the habitat alone in Clear Creek (Alternative No. 2) would increase the salmon run by about 6,000 and the steelhead run by close to 300 fish at an annual cost of only $370,000. Alternative No. 2 is the most cost effective proposal advanced, and of the three, the one that should be adopted first. If Alternative No. 2 does not get the job done, some increase in flows from Whiskeytown Dam may be required.

Battle Creek

Background

Battle Creek, downstream from CNFH, annually supports a large number of fall-run salmon; an average of over 10,000 during the 1981-85 period. In addition, CNFH has handled an average of over 15,000 Battle Creek fall-run salmon and perhaps 1,000 steelhead during the same period.

Very few salmon or steelhead now utilize Battle Creek upstream from CNFH because the habitat is unsuitable for anadromous fish production. Except for a few spring-run salmon, fisheries management personnel now attempt to limit the numbers of salmon and steelhead reaching upper Battle Creek due to the poor habitat.

The principal reason that upper Battle Creek habitat is unsuitable for anadromous fish is because a Pacific Gas and Electric Company (PGE) project provides inadequate flow releases into Battle Creek and does not provide fish screens on its diversions; it does provide fish ladders. The project consists of several storage reservoirs, forebays, powerhouses and canals.

An opportunity exists to restore the salmon and steelhead runs in Battle Creek above CNFH, since the license issued to PGE for their Battle Creek project (Project No. 1121, issued August 13, 1976) by the Federal Energy Regulatory Commission (FERC) clearly states (Article 44, page 32) that "the Commission reserves the right, after notice and opportunity for hearing, to require such changes in the project and its operation as may be necessary to preserve or enhance the environment of the project". A restoration project in upper Battle Creek could result in an increase of 6,000 to 10,000 fall-run salmon and perhaps, 2,500 spring-run salmon, and 1,000 steelhead.

Recommendation

The DFG should conduct a survey of upper Battle Creek (within the areas suitable for anadromous fish) and develop a plan outlining corrective measures that must be taken to assure restoration of the habitat to levels suitable for anadromous fish production. The DFG should then request a FERC hearing and seek to have the PGE project and its operation altered in a manner that will enhance the environment for anadromous fish.

In lower Battle Creek steelhead anglers now wade among spawning salmon, and walk upon their redds. The DFG should conduct studies aimed at determining if such actions by fishermen are adversely impacting salmon production to the extent that steelhead fishing should be stopped in lower Battle Creek.

Butte Creek

Description

There are eight large unscreened irrigation diversions on Butte Creek, along a 25 mile section near Chico. Water enters six of them by gravity and is pumped into the other two. Lower Butte Creek also supports a host of diversions which supply water to commercial gun clubs and agricultural lands. During part of each summer, water in the lower end of Butte Creek is supplemented, and eventually replaced entirely by Feather River water, which is transported via the Western Canal Company Canal. The last of the Butte Creek water is usually diverted above the Western Canal Company dam on Butte Creek.

Studies to determine salmon losses in the unscreened diversions on Butte Creek were conducted during the three year period 1955-57. In 1955 and again in 1957 juvenile salmon were being lost in the irrigation diversions between January and April; none were found either in Butte Creek or in the diversions in 1956. The loss of considerable numbers of adult salmon, in the unscreened diversions (without trash racks) was also demonstrated in May of 1956 and 1957.

In the 1950's when the diversion studies were being conducted, good numbers of spring-run and small numbers of fall-run salmon spawned in Butte Creek each year, but recent estimates (1985) indicate Butte Creek now supports only about 250 spring-run and 100 fall-run fish.

Recommendations

An evaluation should be made of Butte Creek's potential, aimed at determining the feasibility of restoring spring-run salmon populations at least to the 1950's levels of 3,000 to 4,000 fish. Because of the small salmon numbers involved, the benefit-cost ratio may not be great enough to warrant complete restoration, but even grids on the canal intakes would save many adult salmon.

D-019928

LOWER SACRAMENTO RIVER SYSTEM MAJOR PROBLEMS

Feather River

Sunset Pumps Diversion

The major irrigation diversion on the Feather River, Sutter Water District's Sunset Pumps Diversion, located about nine miles north of Yuba City, diverts from the Feather River into the Sutter-Butte Canal (Figure 28). Studies here, like many other studies, indicate that salmon losses in unscreened diversions are a function of the amount of water diverted and the number of fish subjected to the diversion. Studies in 1977 and 1978 show that a fish screen at this diversion would save sufficient juveniles to eventually benefit the ocean commercial and sport fisheries by about $73,000 in a high pumping season and $9,000 in a low pumping season (Table 21). When DFG funding becomes available, a perforated plate vertical fish screen will be installed at the Sunset Pumps Diversion, at an estimated cost of about $100,000.

Feather River Salmon and Steelhead Hatchery

Feather River Hatchery is one of California's newest and most modern hatcheries. Construction was funded by the California Department of Water Resources as a mitigation feature to compensate for the loss of salmon and steelhead runs blocked by Oroville Dam. Operation and maintenance is also funded by the Department of Water Resources, but DFG has the responsibility for operation and maintenance. The DFG provides some funds for rearing fish beyond the mitigation numbers. The hatchery does not have the physical problems that Coleman and Nimbus Hatcheries have.

Production

About 5,000 fall-run and 600 to 900 spring-run salmon are spawned at Feather River Hatchery each year, as well as 1,200 steelhead. Annual production is usually between 11 million and 15 million salmon and about 400,000 yearling steelhead. The present production policy is to release the juvenile salmon at an average weight of 30-40/lb. Releasing salmon of this size results in returns to the ocean fisheries averaging about two percent of those released, but it can be as high as four percent. Most production is either released in the lower Feather River or trucked to the Delta for release.

Thermalito Annex

An enhancement facility, the Thermalito Annex, has been constructed at an estimated cost of $1.6 million, and incorporated into the hatchery production program. Thermalito Annex consists of four large salmon rearing raceways (ponds) with a supply of constant 58 degree (F.) well water. This facility has doubled the rearing area of Feather River Hatchery. Production at the Thermalito Annex totals close to 6 million salmon smolts each year, of which at least 3 million are in the 30-40/lb. size range. A minimum two percent return to the fisheries from the 3 million salmon released at this size should result in an added catch (beyond normal hatchery contributions) of 60,000 fish contributed by Feather River Hatchery.

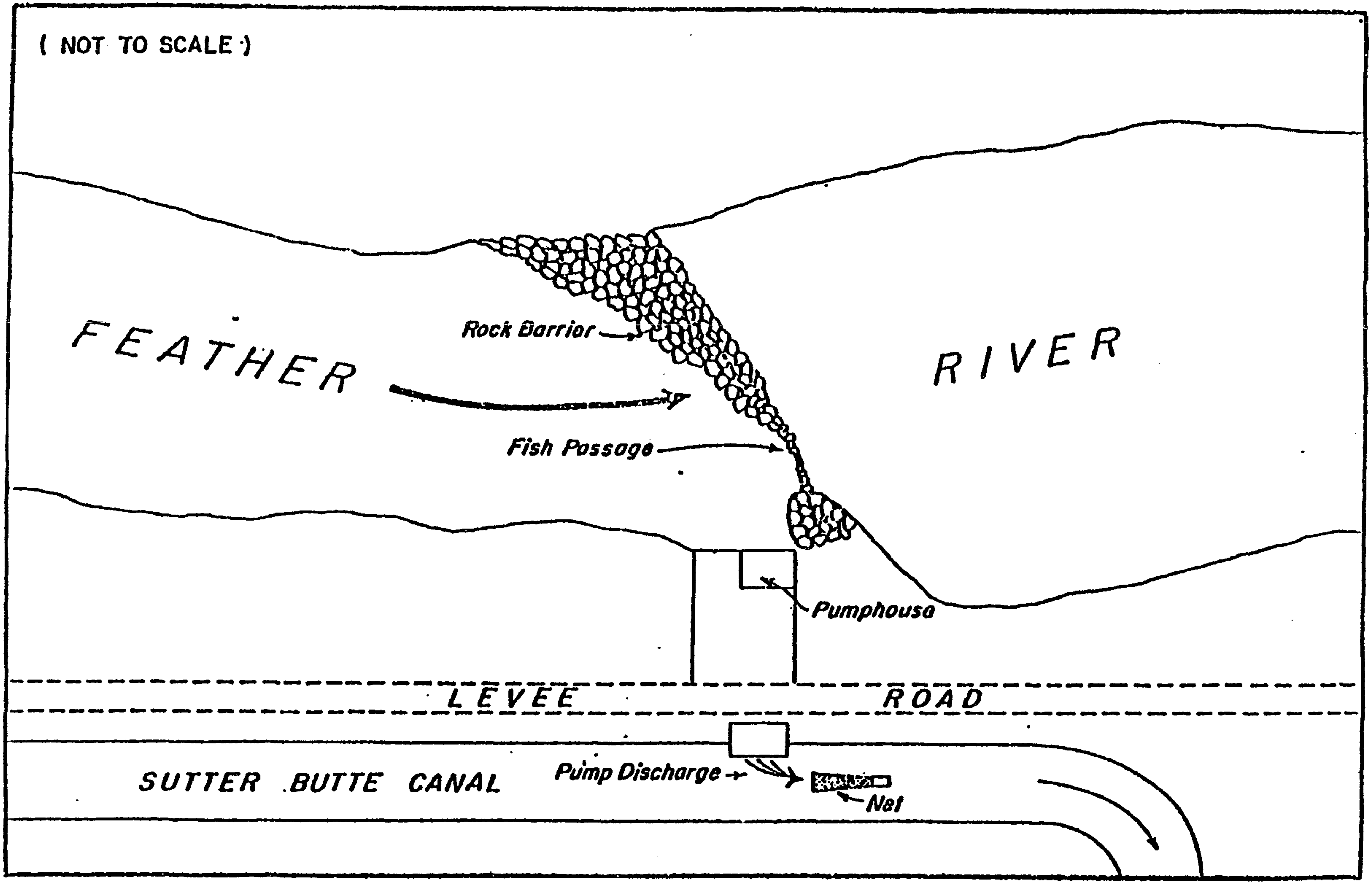

FIGURE 28. Sketch of the Sunset Pumps near Live Oak.

	APRIL			MAY			JUNE			TOTAL	
		Salmon			Salmon			Salmon			
Year	Water Diverted	Number	Average Size mm	Water Diverted	Number	Average Size mm	Water Diverted	Number	Average Size mm	Water Diverted	Salmon Diverted
1969	4,110			11,300			6,880			22,290	
1970	5,387			8,997			8,817			23,201	
1971	0			7,997			6,444			14,441	
1972	3,989			10,217			11,271			25,477	
1973	345			9,668			12,171			22,184	
1974	873			9,818			7,686			18,377	
1975	1,349			9,192			2,902			13,443	
1976	1,728			7,256			3,699			12,683	
1977	8,079	7,546	73.4	9,919	22,300	79.9	5,463	567	85.4	23,461	30,413
1978	0			3,697	3,711	72.8	2,880	176	80.6	6,577	3,887

Table 21. Amount of water diverted (acre feet) by the Sunset Pumps from 1969 through 1978 in critical salmon migration periods, including estimated salmon losses in 1977 and 1978.

Flow Agreement

An agreement and stipulation concerning the operation of the Oroville Division of the State Water Project (July 17, 1967, amended September 18, 1984) between the California Department of Water Resources (DWR) and the California Department of Fish and Game (Feather River Project, FERC No. 2100) is typical of DFG negotiated fishery flow release schedules; i.e., it is an agreement aimed at minimizing fish losses during dry years rather than an attempt to improve production during normal or wet years. Still, it is better than some of the agreements in force today.

A minimum flow of 400 cfs is to be released into the Feather River downstream from the Thermalito Diversion Dam and the Feather River Fish Hatchery, until such time as the Thermalito Diversion Dam Power Plant is completed; releases will then be increased to 600 cfs.

The following minimum flow schedule is to be maintained in the Feather River below the Thermalito afterbay outlet and to the mouth of the Feather River at Verona:

The Preceding April through July Unimpaired Runoff* of the Feather River near Oroville, Percent of Normal**	Minimum Flow Schedule in Feather River below Thermalito Afterbay		
September	October through February	March	April through September
55% or Greater	1,700cfs	1,700cfs	1,000cfs
Less than 55%	1,200cfs	1,000cfs	1,000cfs

*As computed for inclusion in Water Resources' Bulletin 120-xx "Water Conditions in California--Fall Report"

**Normal is defined as the April through July 1911-1960 mean unimpaired runoff near Oroville, 1,942,000 acre feet.

If the April 1 runoff forecast in a given water year indicates that, under normal operation of the project, the reservoir level will be drawn to elevation 733 feet (approximately 1,500,000 acre feet), releases for fish life in the above schedule may suffer monthly deficiencies in the same proportion as the respective monthly deficiencies imposed upon deliveries of water for agricultural use from this project. However, in no case shall the fish water releases in the above schedule be reduced by more than 25 percent.

Water temperature requirements of the agreement are satisfactory for Feather River Fish Hatchery, but they are not specific for the Feather River. The hatchery water temperature schedule follows (a deviation of plus or minus four degrees is allowable between April 1 through November 30):

Period	Degrees Fahrenheit
April 1 - May 15	51
May 16 - May 31	55
June 1 - June 15	56

June 16 - August 15	60
August 16 - August 31	58
September 1 - September 30	52
October 1 - November 30	51
December 1 - March 31	No greater than 55

One problem with the agreement is that it is doubtful that suitable water temperature (as scheduled) for fall-run salmon could be maintained below Thermalito Diversion Dam and Thermalito afterbay during the fall (after September 15) during a dry year. A second problem with the agreement is that during a dry year (like 1987) the water temperature may be desirable for shad and striped bass in the spring, but the flow is not great enough to attract them into the Feather River. A third problem with the agreement is that where the flow schedule is to be maintained all the way to the mouth of the Feather River at Verona, there is no statement as to how far down the Feather River the temperature schedule is to be maintained. This is important because during a normal year about 30% of the salmon spawn in the smaller low flow section (between Thermolito Afterbay and Thermalito Diversion Dam) and 70% spawn in the high flow section (downstream from Thermalito Afterbay). However, during a dry year, when the water temperatures are higher, the spawning distribution reverses and most of the salmon move into and spawn in the cooler low flow section. This latter situation causes considerable salmon production losses in the low flow section due to overcrowding and resulting superimposition of redds.

Recommendations

Funding should be provided to screen the Sunset Pumps Diversion now. The estimated cost is $100,000.

Funds should be provided to purchase one new 25,000 gallon capacity fish planting truck, and preferably two.

A second Thermalito Annex should be constructed and incorporated into the Feather River Hatchery program. This will cost about $1.6 million, plus about $65,000 annually for fish food and personnel. Production will be increased by 3 million smolts at 30-40/lb., and a minimum additional 60,000 salmon will be added to the fishery landings.

Consideration should be given to handling winter-run and late fall-run salmon at Feather River Hatchery.

Yuba River

Problems

There are five main problems on the Yuba River that are causing anadromous fish losses, but the magnitude of these losses is not well documented.

One problem is squawfish predation on juvenile salmon immediately below Daguerre Point Dam, especially during a dry year.

Spring-run salmon have been detected again in the Yuba River, and suction gold dredging in the areas where spring-run salmon "hole up" for the summer is a concern to DFG.

The South Yuba and Brophy Irrigation District diversion (250 cfs gravity flow) is screened with a rock barrier (levee) type fish screen which is presently being evaluated by DFG. If the rock barrier, which appears as a levee, does not work satisfactorily, it is to be replaced with a positive perforated plate

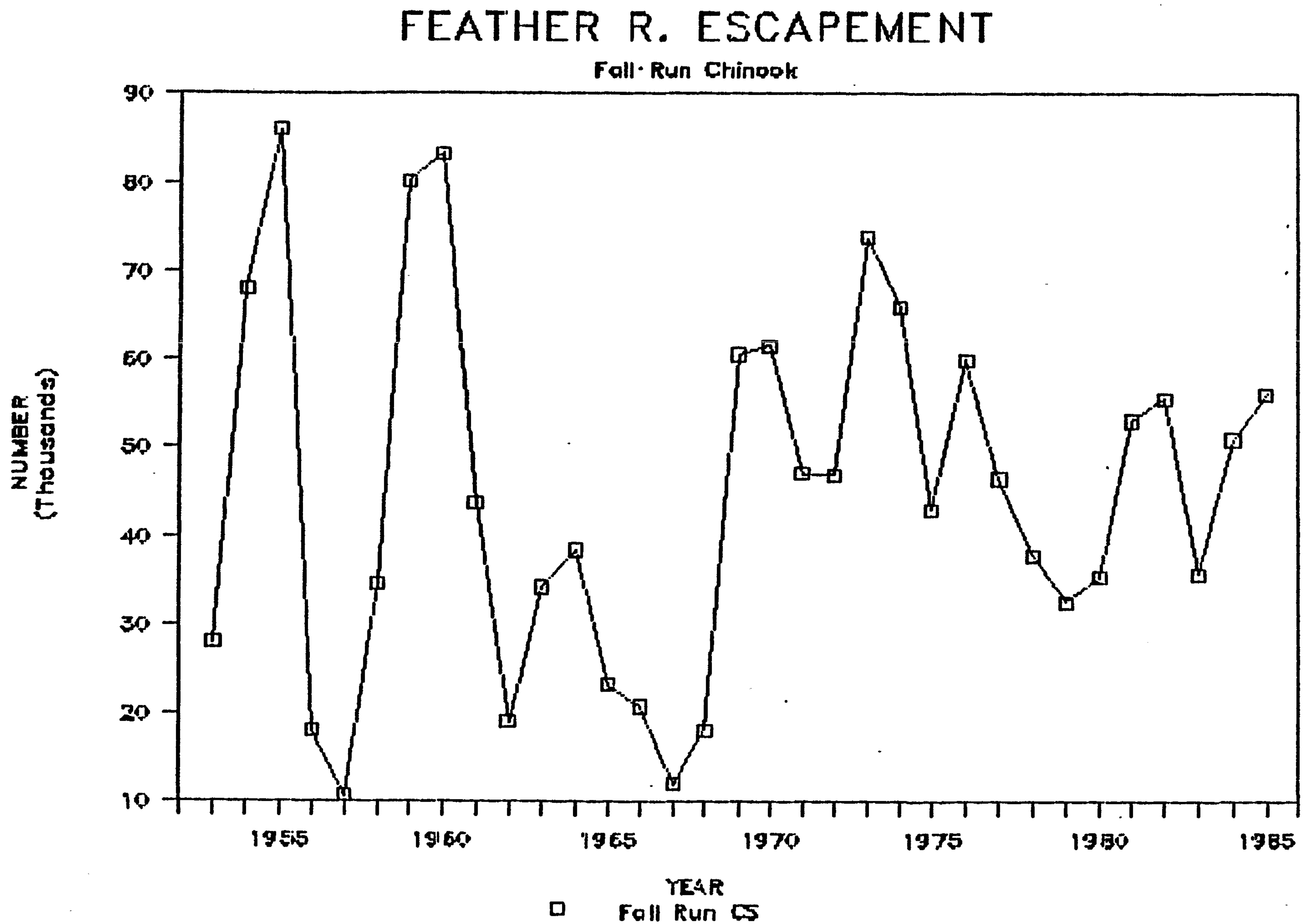

FIGURE 29. Fall-run salmon spawning populations in the Feather River.

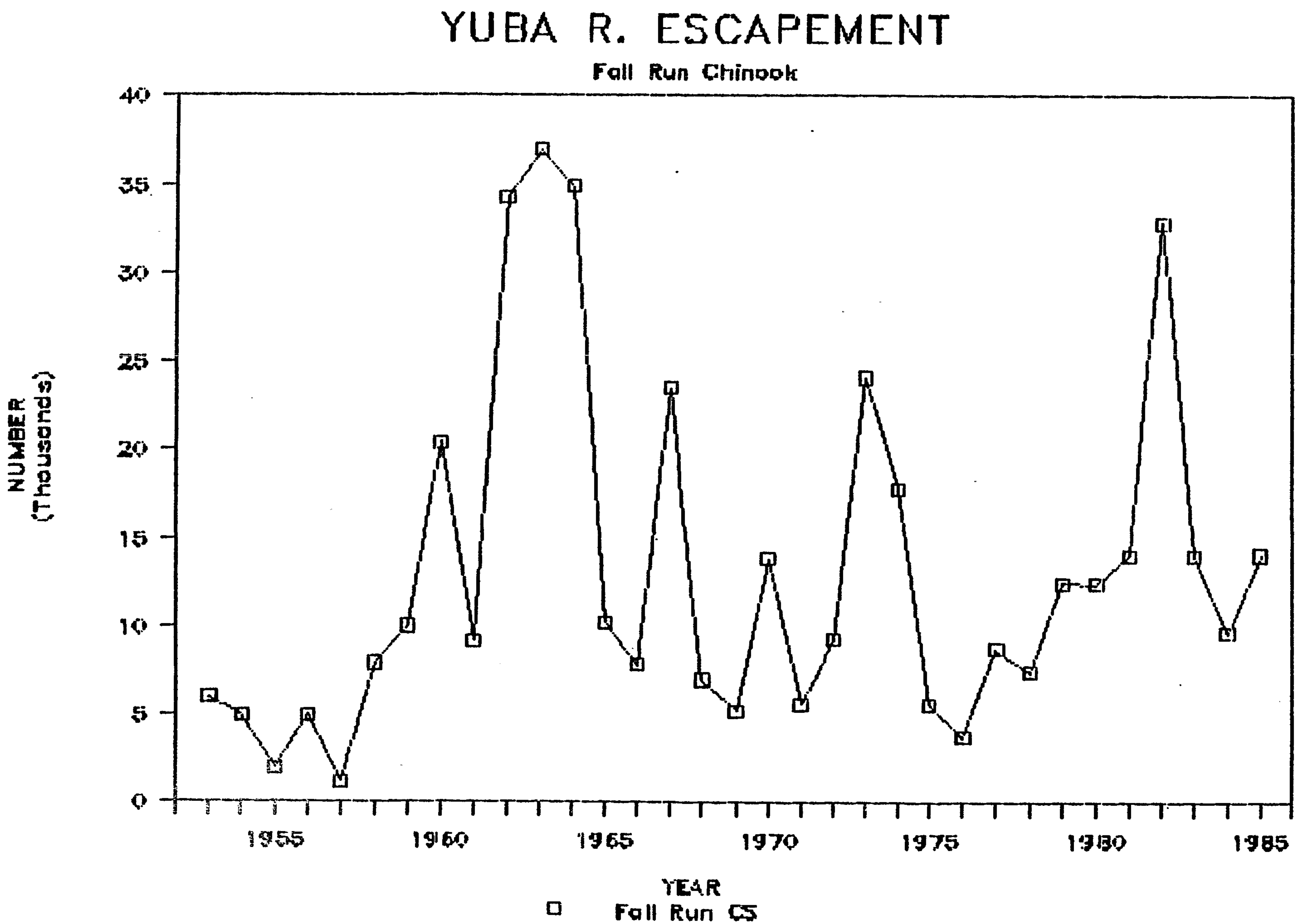

FIGURE 30. Fall-run salmon spawning populations in the Yuba River.

screen.

The Brown's Valley Irrigation District's pump (75 cfs) has no fish screen at present.

Recommendations

Evaluations of the South Yuba and Brophy rock barrier fish screen, as well as the need for a fish screen at the Brown's Valley Irrigation District pump, should be continued, but the evaluations should be funded by the irrigation districts, not DFG, as they now are.

The squawfish predation problem at Daguerre Point Dam should be evaluated, and if necessary a squawfish control program initiated.

To initiate a rebuilding of the spring-run salmon population, the negotiated Yuba River flows of 245 cfs from January through May should be increased. This is the period of adult salmon migration into the river.

American River

Nimbus Salmon and Steelhead Hatchery

Nimbus Salmon and Steelhead Hatchery was constructed to mitigate for the loss of salmon and steelhead populations blocked by Nimbus and Folsom Dams. Approximately 73% of the salmon and 100% of the steelhead in the American River once spawned upstream from Nimbus Dam. Specific mitigation figures for steelhead were never developed because valid preproject data were not available, resulting in the designed hatchery capacity being identified as "30 million salmon and trout eggs"; if necessary, the hatchery was to be expanded to a capacity of 50 million eggs. The operation and maintenance of the hatchery is funded by the Federal Government, and DFG has responsibility for the operation and maintenance.

Production

Between 1956 and 1984, Nimbus Hatchery has produced an average of 15 million salmon annually. Adult returns to the hatchery have averaged close to 12,000 each year. During this same period, the hatchery has reared an average of about 2 million steelhead each year, and there has been an average annual return of 1,500 adult steelhead to the hatchery.

Problems

Nimbus Hatchery has several operational problems, some of which directly affect fish production. Those of particular concern include, (1) an inadequate water supply to the hatchery, (2) poor condition of the adult fish holding pond, as well as low oxygen levels in the water supply to the holding pond, (3) predation of juvenile salmonids by birds, due to lack of anti-predation netting on the rearing ponds, and (4) lack of a second holding pond necessary to eliminate excessive adult fish handling, which results in prespawning mortality.

Prespawning mortality due to handling and low oxygen levels in the water supply typically results in losses of 10 to 20% and has reached as high as 50%. In addition, avian predation has resulted in annual losses of up to 35% of the steelhead fry. Some of the other problems include, (1) overcrowding in the hatchery, (2) flood damage to both the fish ladder leading to the hatchery and to the fish rack which directs adult fish to the fish ladder and hatchery for spawning, (3) inadequate fish feed storage area, and (4) inadequate fish screens.

Modernization Plan

The Bureau of Reclamation and DFG have cooperated in developing a plan to modernize Nimbus Hatchery, but funds have not been available to carry it out. Construction costs of the modernization were estimated at about $2 million, if the work was completed between 1986 and 1992. This plan would primarily assure continued production near present levels, but with a potential of some increased production.

Enlargement Plan

Several plans have been advanced for enlarging the hatchery, and the one which offers the most merit would require an additional 90 cfs of water. At the 1980 cost index this expansion program would cost an estimated $9.5 million, and would increase production by 20 million salmon smolts, and 3 million salmon yearlings (with proper disease control). This could add almost 400,000 salmon to the ocean sport and commercial catch. However, additional legislation might be required, since the Bureau of Reclamation is not obligated to supply water for enhancement, unless their responsibilities for mitigation can be reevaluated favorably in that direction.

Flow Agreement

Instream flow studies conducted by DFG have resulted in a proposed flow regime to provide optimum conditions for the production and survival of salmon in the lower American River. Although further studies may be necessary, the following flow regime should be the basis at this time for a much needed flow agreement.

Period	Flow Range	Critical Habitat Condition Accommodated
Oct 15 - Mar 1	1,750 - 4,000 cfs	Salmon and steelhead spawning and incubation
Mar 1 - Jul 1	3,000 - 6,000 cfs	Salmon and steelhead rearing, shad migration
Jul1 - Oct 15	1,500 cfs	Steelhead and trout rearing

Table 22. Flow ranges encompassing the flow regime required to sustain fish resources in the lower American River.

Recommendations

Nimbus Hatchery should not only be modernized, but also enlarged to reach its maximum production potential.

A flow maintenance agreement should be developed for the lower American River to guarantee continued viability of the fisheries, in view of proposed American River water developments.

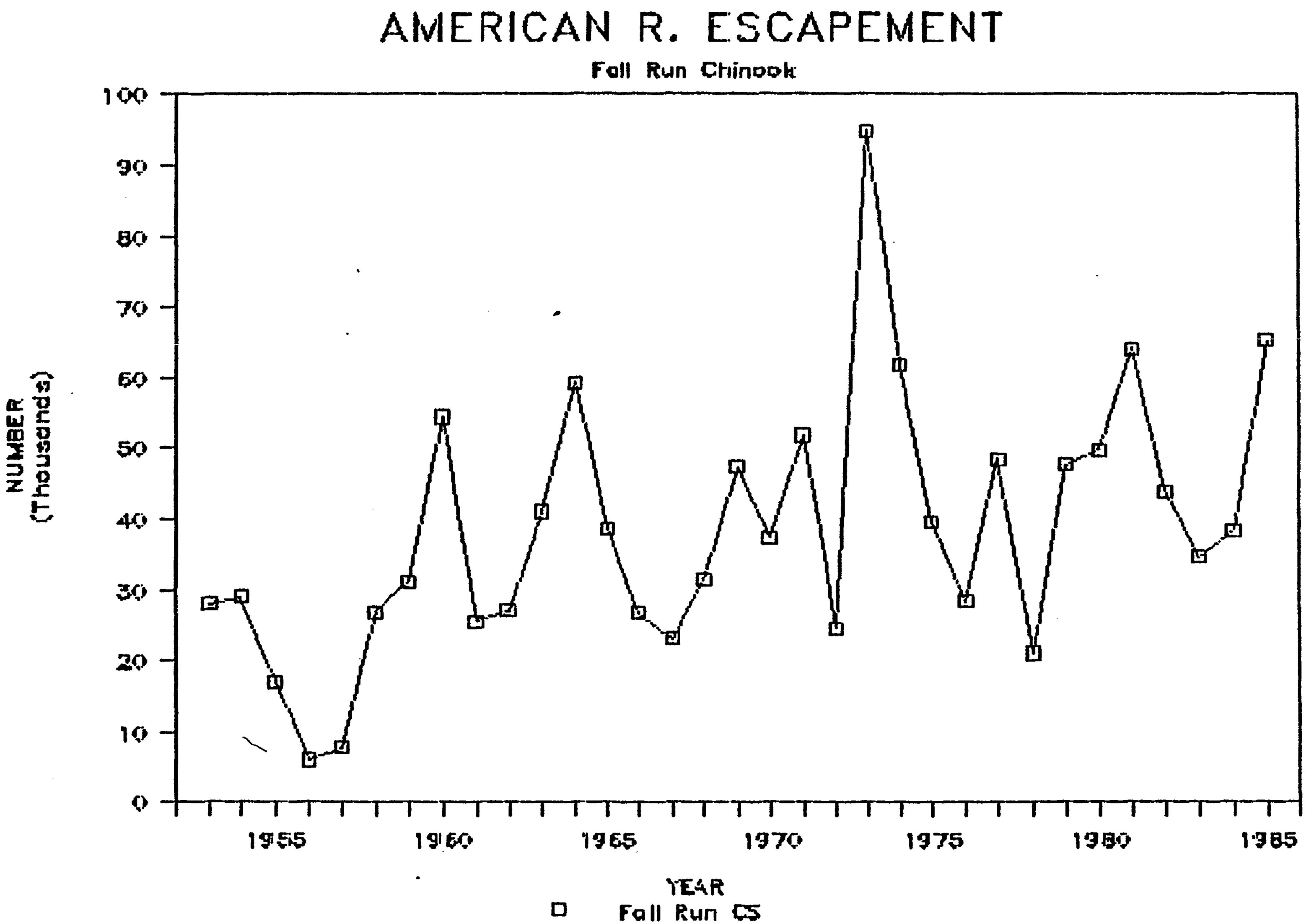

FIGURE 31. Fall-run salmon spawning populations in the American River.

OTHER PROBLEMS

Background

In addition to those streams already discussed, there are 17 Sacramento River tributaries that collectively support populations of about 9,000 salmon and 2,500 steelhead (Table 23). At a two-to-one catch to escapement ratio, they are contributing about 18,000 salmon to the sport and commercial fisheries.

The principal known problems adversely affecting anadromous fish production in these creeks include habitat degradation resulting from natural low flows as well as low flows resulting from water developments, high water temperatures, inadequate fish ladders or fish ladders not kept in adjustment, poaching, lack of fish screens, lack of fish rescue effort, and gravel mining. Relative to gravel mining, in Cottonwood Creek gravel mining is currently reducing by 40% the amount of spawning gravel that it is capable of delivering to the Sacramento River. This is a reduction of 2,700 tons/year.

Two of the streams having considerable potential, but showing an urgent need for corrective actions are Deer and Mill Creeks. Spring-run salmon counts in 1986 showed that only 543 entered Deer Creek and 291 entered Mill Creek. In Deer Creek, the 1986 count is an 80% decline from the 1943-47 mean run size of 2,761. In Mill Creek the 1986 count is an 85% decline from the 1954-59 mean run size of 1,997 fish. Since both streams have fish ladders on dams, and all diversions have fish screens, it is difficult to pinpoint the principal reasons for the population declines. The spring-run salmon populations in Mill and Deer Creeks are genetically distinct populations that spawn in specific areas. They are particularly valuable because they are two of the few remaining true spring-run populations in California. Their current population levels might qualify them for listing as threatened or endangered species.

Another stream with potential is Chico Creek, but aside from low flows, the Lindo Channel Flood Control Project and the M&T Ranch unscreened irrigation diversion at the mouth (which also inhales Sacramento River salmonid juveniles) appear to be the greatest fishery problems.

Recommendations

The DFG should assign personnel specifically to manage these smaller streams as well as the natural production in the larger streams already discussed in this report. Typically, a "stream manager" would be responsible for several spawning streams. His duties would include, but would not be limited to, population estimates, fish ladder and fish screen adjustment, fish rescue, eliminating or at least decreasing poaching, conducting studies relative to the needs for fish screens, fish ladders and stream flows and habitat improvement. The stream manager would "oversee" the populations from the time the adults entered the streams until the juveniles had left.

The DFG should conduct studies on Deer and Mill Creeks, in cooperation with the U.S. Forest Service (part of the watersheds are on Forest Service land), to determine causes of the spring-run salmon population declines, so that corrective actions can be undertaken.

Although not mentioned in the text, primarily because of the scarcity of data, studies should be made to determine the extent of salmon and steelhead losses that occur in the Sutter and Yolo Bypasses as well as in principal agricultural drains, such as the Colusa Drain, so that corrective action may be taken where a need is demonstrated.

Stream	FISH			PROBLEMS									
	Fall-run salmon	Spring-run salmon	Steelhead	Unscreened Diversion(s)	Low flows	Fish ladder(s) needed	Gravel mining	Split channels	Warm water temperature	Fish rescue needed	Antiquated fish ladders	Fish passage problem(s)	Vegetation encroachment
Cottonwood Creek	x	x	x		x		x		x	?			
Thomes Creek	x				x				x	?			
Stony Creek	x				x				x	x		x	
Ash Creek	x				x				x	?			
Cow Creek	x		x	x	x				x	?			
Bear Creek	x				x				x	?			
Paynes Creek	x		x		x				x	?			
Salt Creek	x				x				x	x			
Antelope Creek	x	x	x		x			x	x	x		x	
Dye Creek	x				x				x	x			x
Mill Creek	x	x	x		x				x	?	x		
Toomes Creek	x		x		x				x	x			
Deer Creek	x	x	x		x				x	?			
Singer Creek	x				x				x	x			
Pine Creek	x				x				x	x			
Chico Creek	x	x	x	x	x			x	x	?		x	
Bear River	x		x	x	x	x			x	x			
Dry Creek	x		x	x	x	x			x	x			
Doty Ravine	x			x	x				x	x			
Secret Ravine	x			x	x				x	x			
Auburn Ravine	x			x	x				x	x			

Table 23. Factors adversely affecting salmon and steelhead production in some Sacramento River tributaries.

References

Baiocchi, R.J., 1987. Complaint of California Sportfishing Protection Alliance and United Anglers of California, before the State Water Resources Control Board, against Glenn-Colusa Irrigation District. Mimeographed. April 8, 1987.

Buer, Koll, 1984. Middle Sacramento River Spawning Gravel Study. Calif. Dept. of Water Resources, Northern District. August, 1984.

California Department of Fish and Game, 1953. A preliminary report on the upper Sacramento River water pollution, Shasta County. Prepared for Central Valley Regional Water Quality Control Board.

Citizens Advisory Committee on Salmon and Steelhead Trout, 1971. An environmental tragedy. Report to the California Legislature pursuant to Assembly Concurrent Resolution No. 64, 1970 session.

Finlayson, B.J. and D. Wilson M.S., 1979. Evaluation of lethal levels, release criteria and water quality objectives for an acid mine waste containing copper, zinc and cadmium. Calif. Dept. of Fish and Game.

Decoto, R.J., 1978, 1974. Evaluation of the Glenn-Colusa Irrigation District fish screen. Calif. Dept. of Fish and Game, Anad. Fish. Br. Admin. No. 78-20.

Hallock, R.J. and W.F. Van Woert, 1959. A survey of anadromous fish losses in irrigation diversions from the Sacramento and San Joaquin Rivers. Calif. Fish and Game. Vol. 45, No. 4. pp. 225-296.

Hallock, R.J., W.F. Van Woert and Leo Shapovalov, 1961. An evaluation of stocking hatchery-reared steelhead rainbow trout (Salmo gairdnerii Gairdnerii) in the Sacramento River System. Calif. Dept. of Fish and Game, Fish Bulletin No. 114.

Hallock, R.J. and D.H. Fry, Jr., 1967. Five species of salmon, Oncorhynchus, in the Sacramento River, California. Calif. Fish and Game, Vol. 53, No. 1, pp. 5-22.

Hallock, R.J., 1977. A description of the California Department of Fish and Game management program and goals for the Sacramento River system salmon resource. Calif. Dept. of Fish and Game, Anad. Fish. Br. Admin. Rpt.

Hallock, R.J. and R.R. Reisenbichler, 1979. Evaluation of returns from chinook salmon, Oncorhynchus tshawytscha, released as fingerlings at Coleman and Nimbus Hatcheries and in the Sacramento River estuary. Calif. Dept. of Fish and Game, Anad. Fish. Br. Office Rpt.

Hallock, R.J. and R.R. Reisenbichler, 1980. Freshwater and ocean returns of marked winter-run and late fall-run chinook salmon, Oncorhynchus tshawytscha, from the Sacramento River. Calif. Dept. of Fish and Game, Anad. Fish. Br. Office Rpt., Sept. 15, 1980.

Hallock, R.J., 1980. Returns from steelhead trout, Salmo gairdnerii, released as yearlings at Coleman Hatchery and below Red Bluff Diversion Dam. Calif. Dept. of Fish and Game, Anad. Fish. Br. Office Rpt.

Hallock, R.J., 1981. Effect of Red Bluff Diversion Dam on chinook salmon, Oncorhynchus tshawytscha fingerlings. Calif. Dept. of Fish and Game, Anad. Fish. Br. Office Rpt., Feb. 20, 1981-Revised Jan. 24, 1983.

Hallock, R.J., D.A. Vogel and R.R. Reisenbichler, 1982. The effect of Red Bluff Diversion Dam on the migration of adult chinook salmon, Oncorhynchus tshawytscha, as indicated by radio-tagged fish. Calif. Dept. of Fish and Game, Anad. Fish. Br. Admin. Rpt. 82-8.

Hallock, R.J. and F. Fisher, 1984. Estimated losses of salmon and steelhead attributed to Red Bluff Diversion Dam. Calif. Dept. of Fish and Game, Anad. Fish. Br. interoffice correspondence.

Hallock, R.J. and F. Fisher, 1985. Status of winter-run chinook salmon, Oncorhynchus tshawytscha, in the Sacramento River. Calif. Dept. of Fish and Game, Anad. Fish. Br. Office Rpt.

Kraemer, Thomas J., 1981. The Sacramento River, Glenn, Butte and Tehama Counties. A study of vegetation, deposition and erosion and a management proposal. Calif. State University, Chico. Master of arts thesis.

Menchen, R.S., 1979. Sunset Pumps diversion study, 1977 and 1978. Calif. Dept. of Fish and Game, Anad. Fish. Br. Office Rpt.

Menchen, R.S., 1981. Predation by yearling steelhead, Salmo gairdnerii, released from Coleman National Fish Hatchery, on naturally produced chinook salmon, Oncorhynchus tshawytscha, fry and eggs in Battle Creek, 1975. Calif. Dept. of Fish and Game, Anad. Fish. Br. Office Rpt., July 1981.

Meyers, P., 1985. The economic value of striped bass, chinook salmon and steelhead trout of the Sacramento and San Joaquin River Systems. Calif. Dept. of Fish and Game, Anad. Fish. Br. Admin. Rpt. No. 85-03.

Parfitt, D. and Koll Buer, 1980. Upper Sacramento River Gravel study. Calif. Dept. of Water Resources, Northern Dist., Appendix D., for Calif. Dept. of Fish and Game, Dec. 1980.

Reavis, R., Annual Report, Chinook salmon spawning stocks in California's Central Velley, 1985. Calif. Dept. of Fish and Game, Inland Fish. Div., Admin. Rpt. No. 86.

Reisenbichler, R.R., J. D. McIntyre and R.J. Hallock, 1982. Relation between size of chinook salmon, Oncorhynchus tshawytscha, released at hatcheries and returns to hatcheries and ocean fisheries. Calif. Fish and Game, Vol. 68, No. 1, pp. 57-59.

Reisenbichler, R.R., 1986. Use of spawner-recruit relations to evaluate the effect of degraded environment and increased fishing on the abundance of fall-run chinook salmon, Oncorhynchus tshawytscha, in several California streams. University of Washington, doctoral dissertation.

Sholes, W.H. and R.J. Hallock, 1979. An evaluation of rearing fall-run salmon, Oncorhynchus tshawytscha, to yearlings at Feather River Hatchery, with a comparison of returns from hatchery and downstream releases. Calif. Fish and Game, Vol.65, No. 4, pp. 239-255.

Snider, W.M. and Eric Gerstung, 1986. Instream flow requirements of the fish and wildlife resources of the lower American River, Sacramento County, California. Calif. Dept. of Fish and Game, Stream Evaluation Rpt. No. 86-1.

Upper Sacramento Salmon and Steelhead Advisory Committee, 1983. Red Bluff Diversion Dam and Tehama-Colusa Fish Facility, Rpt. No. 1, July, 1983.

Upper Sacramento River Salmon and Steelhead Advisory Committee, 1984. Coleman National Fish Hatchery. Rpt. No. 2, Aug., 1984.

Upper Sacramento River Salmon and Steelhead Advisory Committee, 1985. Chico Landing to Red Bluff Project. Rpt. No. 3, March, 1985.

Upper Sacramento River Salmon and Steelhead Advisory Committee, 1986. Glenn-Colusa Irrigation District Diversion and the Sacramento River fishery. Rpt. No. 4, Sept., 1986.

U.S. Bureau of Reclamation, 1983. Central Valley Fish and Wildlife Management Study; Fishery problems at Anderson-Cottonwood Irrigation District Diversion Dam, Sacramento River, California. Special Rpt. July, 1983.

U.S. Bureau of Reclamation, 1985. Central Valley Fish and Wildlife Management Study; Fishery problems at Red Bluff Diversion Dam and Tehama-Colusa Fish Facilities. Special Rpt. December, 1985.

U.S. Bureau of Reclamation, 1986. Central Velley Fish and Wildlife Management Study; Evaluation of the benefits and costs of improving the anadromous fishery of Clear Creek, California. Special Rpt. June, 1986.

U.S. Bureau of Reclamation, 1986. Central Valley Fish and Wildlife Management Study; Nimbus Hatchery Enlargement. Special Rpt. June, 1986.

U.S. Bureau of Reclamation, 1986. Central Valley Fish and Wildlife Management Study; Temperature and flow studies for optimizing chinook salmon production, upper Sacramento River, California. Special Rpt.

U.S. Fish and WIldlife Service, 1983. Evaluate the need for fish screens on diversion facilities along the Sacramento River. Appraisal Report on problem A-8 of the Central Valley Fish and Wildlife Management Study, October, 1983.

Vogel, D.A., K.R. Marine and J.G. Smith, 1987. Fish action passage program for Red Bluff Diversion Dam; 1986 annual progress report. U.S. Fish and Wildlife Service, Rpt. No. FRI/FAO-87-6.

Vogel, D.A., 1987. Estimation of the 1986 spring chinook salmon run in Deer Creek, California. U.S. Fish and Wildlife Service, Fisheries Assistance Office, Red Bluff, California. Rpt. No. FRI/FAO-87-3.

Vogel, D.A., 1987. Estimation of the 1986 spring chinook salmon run in Mill Creek, California. U.S. Fish and Wildlife Service, Fisheries Assistance Office, Red Bluff, California, Rpt. No. FRI/FAO-87-12.

Walsh, R., 1987. Complaint by the California Sportfishing Protection Alliance and United Anglers of California against the Glenn-Colusa Irrigation District. Letter from State Water Resources Control Board to Robert Clark, Manager, Glenn-Colusa Irrigation District, May 11, 1987.

Printed by
Department of Water Resources
Reprographics